MINISTRY OF WORKS

NEW ZEALAND

SOME ASPECTS of ROADING and RELATED WORKS

JUNE 1959

200

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Comment by

F. M. HANSON, Commissioner of Works.

INTRODUCTION

The purpose of this publication is twofold. In the first place it was expected that the preparation of the respective papers would require some investigation and reading and would call for preliminary discussions with more experienced senior engineers. This would be good training for the Authors. Secondly, it was hoped that the resulting papers would serve as valuable technical information to all engaged on roading and related works.

It is felt that these two aims have been fully achieved. I congratulate the Authors and those who have helped and advised them. They can all take satisfaction from the knowledge that their efforts undoubtedly will be to the benefit of roading in New Zealand.

I have no hesitation in publishing the papers as a guide to all engineers who may want information on any of the subjects covered. Very little editing has been done. Except for those on Vertical Sand-Drains the papers have been published almost as submitted.

Comment has been made only where it was thought that modifications or additional information would make some further worthwhile contribution on the subject.

F. M. Hanson
Commissioner of Works

June 1959

CONSTRUCTION OF METAL COURSES OVER CLAY FOUNDATIONS WITH PARTICULAR REFERENCE TO THE SUB-BASE EXPERIENCE IN NORTHLAND

By G. P. Keller

1. Introduction

These notes are prepared to give a general impression of the design considerations and construction factors which are present in most road-building activities in Northland. It cannot be claimed that all highway construction is given "the full treatment", but a serious attempt is being made to ensure that the principles involved are recognised and practised by construction staff. A testing laboratory has been established and this is playing an increasing part in soil testing prior to and during construction, in the testing of road metals, and in general investigations.

2. General

More than half of the land areas north of Auckland City consist of Sedimentary rocks of the Waitemata, Whangarei and Onerahi beds of Cretaceous and Tertiary periods.

Overlying these sedimentaries is a surface layer of clay generally from 5 to 15 feet in thickness. It is the treatment of these clays which presents our greatest single problem in road construction. The interfacial layer between the clays and the rock is often badly weathered - commonly a mudstone reverting to clay. This leads to the formation of weak planes on which sliding occurs. The clays all have high plasticity with liquid limits up to 100% and Plastic limits up to 40%. Natural moisture contents are high (40% to 70%) due to the wet climate and to the fact that much indigenous bush cover has been stripped in the past century, thus increasing the percentage of rainfall soaking into the soil. A further climatic feature is the common occurrence of long droughts in the early months of the year. In these periods of drought the clays which are very sensitive to changes in moisture content shrink, with cracks reaching several feet deep.

3. Drainage

As an illustration of the sensitivity of Northland clays to water, a C.B.R. Value of 15% at 35% moisture content may fall to something like 2% at 45% moisture content. The provision of adequate drainage of the sub-base is therefore vital.

Drainage starts at the lowest level which can cause trouble - the interfacial zone between the underlying rock and the clay. Slides on this zone are not uncommon. This

zone is usually of several feet in thickness, and is frequently saturated. The procedure is to remove the overlying clay and loose rock, bench the firm rock, and instal a drainage system in the rock. Drains here are usually 6" unreinforced concrete pipe, with a surround of porous "pea-metal", and a covering of manuka bush to exclude filling material.

On many of the older sealed highways in Northland the edges of the seal in cuttings are developing longitudinal depressions, resulting from heavy wheel loads always following the same track, and poor drainage (plus possibly inadequate metal depth) of the roadway. This phenomenon is referred to later under "lateral stability". Where faulty drainage is suspected, shoulder drains are sometimes installed, but these are expensive and difficult to build properly under traffic, and they are also vulnerable to wet weather during construction. A preferred method is to open up wide and deep watertables wherever possible - to a depth of 2 to 3 feet below the level of the edge of seal, and a distance out of 6 to 12 feet. Such watertables are not so liable to blockage by slips from batters as are narrower ones.

4. Compaction of Earthworks

In dealing with clays of a critical moisture content and with the wet weather which is frequently encountered during the construction season, compaction of embankments is far from being the well controlled precision operation that one would like. When excavated material is suitable apart from an excess of water, it is usually better to spoil such material and import something better. It is not usually feasible to spread material so that it will dry, and then use it. In this connection, it is a fact that in the poorer classes of country, better results are obtained by the use of small construction plant, which does not move such big yardages, and allows better control during the course of the work. In such country also, every effort is made to keep embankments and cuttings as shallow as possible. It is considered better to work to say a 40 m.p.h. alignment with cuts and fills of the order of 10 feet maximum rather than go to 50 m.p.h. alignment with heavier earthworks. Traffic densities, by normal standards, are light - of the order of 200 v.p.d. and upwards.

Compaction is normally done by tamper and given thin spreading of material and the correct number of passes by the

compactor, reasonable results are obtained. Checks are made by field density measurements - a procedure yet to be fully employed. No work has been done with the addition of lime to the clay.

5. Sub-Base Course

The provision of a layer to offer complete separation of the natural subgrade and the load-carrying metal top is a "must" on much of our work. The function of this layer is twofold - to prevent clay from the foundation making its way up into the metal, and to prevent water from getting through the metal to the clay. Its grading, therefore, is of some importance. Three classes of material have been used with some success - graded river shingles (gravel, sand, silt), sandstone (really a lightly consolidated fine sand), and volcanic tuff. Of these alluvial material where available is considered the best. Tar or bitumen membranes have not been used.

6. Design of Metal Courses

Thicknesses of base and top course are determined largely by experience, with, where possible, a check by the C.B.R. Method. In this connection, it is considered that considerable savings would be possible if the grading of our metals were closer to the N.R.B. standard specification, and efforts are being made in this direction with the co-operation of quarry operators. However, it is a fact that it is not possible to produce enough fines from a rock quarry without excessive cost. Where possible graded river gravels are crushed, and these have given much better results although they are still, according to the curves, short of fines. Sometimes, of course, the river material will result in an excess of rounded particles, and to overcome this efforts are made to combine alluvial material with crushed rock. This last should give good results where it can be achieved, but it has to be admitted that availability of materials and the leads involved have a critical bearing on the economics of the situation.

7. Highway Cross-section and Lateral Stability

Reference was made earlier to the deformation of the shoulders of our highways being sometimes due to poor shoulder drainage. It is possible that this trouble may be the natural result of a combination of factors not including poor drainage, but consisting of (1) the tendency of slow-moving heavy vehicles to hug the left hand side of the seal to facilitate

overtaking by faster traffic, (2) the need for watertables to be deep enough to provide adequate drainage, and (3) a natural desire to keep earthwork quantities to a minimum, resulting in formation widths somewhat narrower than ideal.

Some form of stabilisation is indicated, such as a concrete kerb or deep penetration of metal by a bitumen, or perhaps we are trying to build with metal shoulders of inadequate width.

8. Soil Mechanics

As a tool, Soil Mechanics is of very real value, and is being used as widely as possible. The normal tests carried out are for Plastic Index, Unconfined Compressive Strength and Natural Moisture Content. In conjunction with close site inspection, the results obtained are of great value in designing slopes of batters in cuttings, the value of material for fillings and as a foundation for embankments, and generally in allowing the most economical use to be made of the materials available. All boring has been done by hand auger, and depths of up to 33 feet have been reached where special circumstances have made this necessary. Ground water level is recorded when boring is done.

Conclusion

These brief notes can make no claim to be either comprehensive or conclusive and they introduce nothing fundamentally new. They do, perhaps, indicate the kind of problems which are inherent in road-building in Northland and some of the ways of overcoming them. Techniques will change, but the basic concepts of sound design, good drainage, adequate compaction and strong metal courses must always be paramount. An active recognition of these concepts by all staff involved in road design, construction and maintenance, can only result in better roads.

COMMENT

by F. M. Hanson

Emphasis should be placed on some aspects of roading in the very plastic clays of Northland.

1. Control of Compaction Water

The application of water for the compaction of metal courses should be very carefully controlled. It is believed that some of the roading troubles in Northland have resulted from, or at least have been initiated by, perhaps only slight

over doses of water sprinkling especially in the initial stages of metal course compaction.

It must be borne in mind that the metal course is loose and unbonded when sprinkling commences. The water percolates right to the bottom of the metal and while the surface moisture may evaporate until the surface becomes dry and dusty, the water lower down in the metal course remains. More water is added to abate the dust and to provide bonding of the surface. Some of this again evaporates and further water is added. Although the minimum of water may seem to be applied the bottom moisture is never allowed to evaporate and this is locked in when the seal coat is applied. The water gravitates to the clay sub-grade which becomes over-moist and as a result slight plastic deformations begin to occur.

Bad heaving or potholing may not be readily apparent for several years depending somewhat on the traffic weights and densities. Of course, inadequate drainage, perched water-tables, unprotected shoulders or cracked sealing will accelerate the deterioration.

It will be appreciated that similar troubles will not arise to the same extent in the case of those districts where the sub-grades are non-plastic and free draining. Also, if a good layer of suitable sub-base material is applied under the metal course the locked-in moisture spreads and adheres in a very thin film to the surface of the individual fragments of the sub-base and there may never be enough water to reach the sub-grade. Even if some free water does reach the sub-grade the fine sandy material of the sub-base will not permit the clay sub-grade to work up into the sub-base and metal course.

I believe that the old roller compacted water-bound macadam topcourse construction avoided any excess of moisture in the road structure. Also the former practice of maintaining the topcourse with a mulch of chips instead of frequent applications of water did much to prevent any build up of free moisture in the road structure.

If because of rains or for any other reason, an excess of free moisture cannot be kept out of the road in the heavy clay areas, it may be necessary to change completely the traditional methods of construction. There are two or three alternative methods which could be adopted. It could be too, that the cost is not excessive and that there will be less discomfort and inconvenience to traffic. If research shows that under the present methods of construction it is not

practicable to prevent an excess of moisture being locked in the metal course, then a bituminous penetration course or some similar pavement may have to be substituted for the macadam topcourse.

Penetration is a strong durable type of construction but suffers from the fact that very skilled operators are required for a smooth riding finish. This drawback can be overcome by blinding the freshly penetrated stone with a fine grade of plant mix (all passing $\frac{1}{4}$") at a rate of about one to one and a half tons to 50 square yards of surface. With careful grader operation the plant mix can be applied to a very true finish without disturbing the penetrated metal. In some districts hot bitumen penetration could be adopted, but where rain showers are likely to be frequent or when cool weather may obtain, bituminous emulsion would be preferable for penetration work. If this class of work becomes necessary further instructions will be prepared.

2. Sub-Base

I agree with Mr Keller that a sandy river shingle (builder's mix) is a very satisfactory sub-base. The sub-grade should be properly shaped and compacted and then, in this heavy clay area the sub-base material should be applied for the full width of formation from watertable to watertable in cuts or to the edge of the formation in fills. A sub-base restricted in width to the width of sealing is not satisfactory. There must be free drainage from the sub-base to side drains or watertables.

3. Metal Depth

There is often confused thinking about metal depth requirements not only in the clay areas, but also in the wider field. May I refer engineers to the notes on this subject in my report on Tasmanian Roading. I believe that familiarisation with the formula set out in the Tasmanian Report will give a better understanding of sub-base and metal layer depths.

$$d = r\sqrt{\frac{P}{p} - 1}$$

Where d = depth of pavement in inches.

r = the radius in inches of the equivalent circle of the contact area between the loaded tyre and the road. The area of this equivalent circle for practical purposes may be taken as the wheel load in pounds divided by the tyre pressure in pounds per square inch. This gives the area of the

circle in square inches from which the radius r can be found. Assuming, for design purposes axle loads of 18,000 lbs, with tyre-pressures of 80 lbs, the radius r may be taken as 6 in. for all metal depth calculations.

P = tyre pressure in pounds per square inch

p = bearing value in pounds per square inch of the subgrade or the soil layer on which the next layer of pavement is to be built.

By proper construction methods and reasonable drainage it should be possible to maintain the Northland clay sub-grades with a C.B.R. between 5 and 10 which is the same as a bearing value of between 10 and 20 lbs per square inch. At the lower bearing value of 10 lbs per square inch total thickness of sub-base, metal and bituminous surfacing should be about 14" for 6½ ton axle loads. This might well be made up with 10" of river shingle sub-base followed by 3" of crushed metal covered with a prime and seal coat. If it is desired to achieve Class I or 8 ton axle loads the metal and sealing should remain the same but the river shingle sub-base should be increased to about 12".

The common practice of applying 3" or 4" of sub-base and 10" or 12" of crushed metal and seal does not give added strength. It is just as strong and generally much cheaper and also easier, to lay 10" or 12" of sub-base followed by 3" of crushed metal course. It is true that the sub-base material influences the layer thickness, but even pure sand sub-base should be about 9" thick with the crushed metal course plus seal of the order of 5". To determine these layer thicknesses I have taken tyre pressures at 80 lbs per square inch, and it is safe to assume that sand will have a bearing value better than 40 lbs per square inch.

The following table sets out C.B.R. and equivalent bearing values:-

C. B. R.	Bearing Values lbs. per sq.in.
2	
2	5
5	10
10	20
15	25
20	30
35	40
50	50

It is safe to say that in many cases throughout the country too much crushed metal is used and not enough free draining sub-base material.

4. Metal Fines

Mr Keller has been troubled by a deficiency of fines in the crushed metal course. This will frequently be the case with a single crushing. It is therefore necessary to produce or obtain extra fines. This may be done by a second crushing of some fraction of the metal. A second crushing costs money but the saving in compaction will more than offset the cost of crushing. The proper amount of fines gives almost immediate compaction and less hindrance and discomfort to the motorist.

5. Preston Bypass Failure

In view of my comments on trapped compaction water and our views on the need for a free draining sub-base material, the following report just received on the Preston Bypass motorway failures is of interest. I am indebted to Mr M. A. Craven of New Zealand Portland Cement Association for this information -

"The construction of the Preston Bypass consisted of 3¼" of bituminous surfacing laid on a 9" base of pre-mixed water bound macadam. The sub-base consisted of shale and the thickness varied depending upon the C.B.R. of the formation, but an average thickness would be about 15 inches. Concrete marginal strips about 12 inches square were laid either side of the carriageway. The areas which failed were distributed along considerable lengths of the motorway but were small in area and showed themselves in the form of surface rutting. As far as can be gathered, the cause of the trouble was the trapping of water between the concrete haunches which could not get away because much of the surface of the shale sub-base was impervious. Weather conditions were bad during much of the construction period and there is no doubt that some of the pre-mixed water-bound macadam base was very wet indeed. The bituminous surfacing was not impervious and the water in the base would undoubtedly have been augmented by percolation from the surface. Freezing of the trapped water resulted in disruption of the base and the top of the sub-base, thus causing lack of stability and failure in patches."

Extract from "The Surveyor & Municipal
& County Engineer", 31 January 1959,
P.98.

MINISTER'S REPORT ON PRESTON BY-PASS

'Defects due to excess moisture in base course'

The Minister of Transport and Civil Aviation, Mr Harold Watkinson, received the preliminary report of his deputy chief highways engineer last week. As a result of this report, the Minister assured the House of Commons that the damage was due to the weather. The Minister circulated the following report:

It was clear from preliminary site investigation that soil conditions would be poor and care would be needed in preparing foundations. Bearing this in mind, and with the high embankments required in places the county surveyor's proposal for flexible construction was agreed. This particular form of flexible construction has been used in Lancashire since 1952 without reports of failure.

The design adopted comprised a thin layer of ashes on the formation and on this a sub-base of compacted colliery shale of varying thickness dependent on the quality of the ground. The base consisted of pre-mixed water-bound macadam 9 in. thick, and the surface construction was 2½ in. of tarmacadam with a temporary running surface of cold asphalt 3/4 in. thick. The laying of this temporary surface was in accordance with past practice in view of the usual risk of settlement of embankment work. Flush marginal strips in concrete 12 in. wide by 12 in. deep were laid along each edge of carriageway to give support to the layers of the carriageway construction and to define the sides of the road.

As stated above, the road was completed and opened to traffic on 5 December 1958. Severe frosts occurred early in January when temperatures as low as 27 degrees of frost were recorded. The average temperature for the first three weeks of the month was, in fact, the lowest for 47 years. Following an exceptionally rapid thaw on the night of 17-18 January defects were observed on 20 January on some areas of carriageway. The county police considered conditions were dangerous for high speed traffic and it was decided, on their advice, to close the motorway on the morning of 21 January. Investigations showed that there were about 15 areas of varying size where some deformation and crazing of the surface had occurred.

APPENDIX

Early overlay work in Hawke's Bay cost approximately £30-£35 per chain for consolidation. This has been reduced by change in methods to £10 per chain or thereabouts. The changes have been:-

1. The restriction of the grader's activities to a periodical brushing of the surface to maintain the correct shape. The former practice was to work the grader at the same time as the iron tyred rollers, each machine undoing the work of the other to some extent.

2. Elimination of sheepsfoot and wobbly wheel rollers.

Present practice is to spread the metal by truck as near as possible to where it is wanted, consolidate with iron tyred rollers, then a light brush with the grader to maintain shape, and then further iron tyre rolling.

With the predominantly rounded stone of the Hawke's Bay metals and lack of fines in the grading, the grader was found to shake the fines to the bottom of the metal leaving a hungry metal on top. Use of the iron tyred roller without the grader on the other hand tends to choke the surface metal with freshly fragmented stone.

Water can be dispensed with entirely in the consolidation of metal in winter months. The usual mode of application of water through a perforated bar gives too liberal an application of water and is in no way comparable with fine misty rain. Most of the water which falls on the road from a perforated bar goes through the unconsolidated metal down to the old road surface where it does no good and could do much harm.

To digress a little, pressure application of water in the form of a fine mist is, I think, a must in metal consolidation on new clay formation where it is most important to keep the clay dry while metal is being built up to a depth suitable for carrying loads over a wet clay. On recent metal consolidation over 3½ miles of new formation 12" consolidated depth of metal was laid between January and July without the application of any water.

Considerable difficulty has been experienced from time to time with the consolidation of the metal on shoulders. The iron tyred roller has a tendency to chase the shoulder metal sideways. Traffic consolidation can be useful on the shoulders and a good way of getting traffic onto the shoulders is to make transverse hurdles of unconsolidated metal about 6" high

2. Survey and Setting Out

The existing highway alignment is surveyed and curves designed to fit the alignment. The correct amount of super-elevation is then applied to the lift pegs on the curves. Lift pegs are put in at chain intervals on the straights.

3. Metal Spreading

The overlay metal is spread on the road by contract and compacted in layers of 4" loose depth by departmental forces and equipment. Formerly medium sealing tar was applied to the old surface as a tack coat for the overlay metal and as a blanket protection against intrusion of clay through failures in the old surface. The tar application has since been abandoned in favour of an extra 2" - 3" of metal at an equivalent cost.

4. Sealing

Sealing with medium sealing tar and grade C chip is carried out usually by contract. If tar is not available MC_3 is used on summer work. In recent contracts payments for spreading the chips has been made by the sq. yd in order to make overchipping unprofitable.

COST (See Appendix)

Costs of a typical mile of this work are:-

Survey and setting out	£100
9" av. depth loose metal, 4,500 c.yds. @ 25/-	5,625
Consolidation 80 chs. @ £10 per chain	800
Sealing 4000 gals. @ 4/- per gallon	800
180 c.yds. chips @ 40/-	360
	£7,685

The most variable item in the above costs is the metal which could vary from 10/- to 30/- per cubic yard. Consolidation cost per c.yd. varies greatly with the efficiency of the supervision, but on a well directed work this item amounts to from 4/- to 5/- per cubic yard irrespective of whether the metal is 100% crushed or screened river metal.

GENERAL

Overlay work is particularly suited to the winter months and can therefore be carried out without detriment to the essential summer work, earthworks and metalling of new earthworks.

OVERLAY METHODS IN HAWKE'S BAY

By J. J. Neale

USES

1. As a means of increasing metal depths on a sealed road failing through insufficient metal depth.

2. As a means of shape correction of a sound but badly shaped road.

3. As a means of road strengthening to cater for a higher loading classification.

Overlay takes full advantage of the strength of the existing road surface.

Small length overlays of failed areas are particularly suited to strengthening on curves since the lifting of the surface does not appear as a hump in these circumstances.

Where failures are confined to local patches possibly subject to wetter conditions than the remainder of the surface then digging out of the failures is a cheaper process than complete overlay.

Digging out failures becomes uneconomic compared with overlay if the area dug approaches half the total surface area of the roadway. However, in point of fact overlay is adopted in preference to digging out, on failed sections where less than half the area is in failures since overlay gives the better riding surface and lifts the road further above ground water level.

PROCEDURE

1. Strengthening of localised weaknesses

This is done in certain cases only. The minimum depth of overlay metal is that depth required over the weakest part of the old surface. This minimum can sometimes be decreased by strengthening the weakest areas by digging out.

This could involve digging out of localised failures in the old surface or cutting out weak shoulder material and backfilling with metal prior to the main overlay.

Digging out failures is carried out in Hawke's Bay by hydraulically operated rubber tyred tractor mounted back acting shovel under contract payment per square yard of hole dug. The depth of digging is stated in the contract and is usually 12".

compaction, etc. are continuously determined. There has been a tendency to be far too precise in regard to some of the physical tests of bitumens and tars. Small climatic variations could have a much greater effect than a few seconds viscosity and so on. Bitumen tests and testing should always be approached with a commonsense view.

The paper by Mr Pollock has laid down a reasonable laboratory setup for the average district, but all districts will not have exactly similar requirements. Even small sub-offices may require the means for sieving concrete aggregates, road metals and foundation soils, together with the apparatus for determining Plastic and Liquid Limits.

As Mr Pollock has pointed out a laboratory must be considered as an important part of any roading organisation and it is not sufficient that all testing should be left to laboratory assistants. It is also essential that engineers should make themselves completely familiar with tests and testing.

COMMENT

By F. M. Hanson

It is agreed that District laboratories in themselves should not be equipped to undertake comprehensive research programmes, but at the same time District laboratories can make a very valuable contribution to research. Road research which should be carried out in New Zealand will be, as a general rule, more in the nature of applied research rather than basic research. Such applied research will be the responsibility of every engineer engaged on roading and the District laboratory will be called upon to conduct a continuous programme of examination, testing, recording and so on.

It is most important that full particulars of all roading should be recorded in some strong book form and kept available for ready reference. If a continuous history of every road were maintained such information would be very helpful indeed and would in itself be a valuable contribution to research. The laboratory might well be responsible for recording information supplied by the engineers or overseers together with test results and laboratory information.

It would be desirable to have a full history of every road or suitable sections of road from the time construction was commenced. This is not always possible and indeed where historical records have not been previously kept it may be necessary to start long after the road has been sealed. Although it is preferable to commence the records at the earliest possible date, it is never too late to make a start. When a late start is made the introductory paragraphs could consist of whatever information can then be obtained as to the previous road history.

The main matters to be recorded are the techniques employed and the materials used, but there aremany surrounding items which will be valuable in later years. For example, weather conditions during construction, traffic which has obtained, any flooding or submersion of the road, time of the year when operations were carried out, subsequent maintenance, and so on. In fact any item should be logged which could in any way have some bearing on the service of the road.

As a general rule districts should not have to undertake the testing of bituminous materials as a matter of routine control procedure in the way that metal gradings and subgrade

APPENDIX

Minimum Equipment Required for a District Laboratory

Portable engine driven coring drill rig up to 300-400 ft capacity.
Hand driven penetrometer to 50 ft.
Post hole auger to 16 ft.
C.B.R. test apparatus.
Los Angeles abrasion test machine.
Compression testing machine 100 ton capacity.
2 cu. ft engine driven concrete mixer.
Liquid limit and Plastic Limit apparatus.
Standard Proctor equipment.
Drying oven and hot plate.
Curing tank or fog cupboard.
Sets of sieves from 3" to No. 200 mesh.
Washing sieve No. 200 mesh.
Mechanical shaker for sieves.
Sand or oil containers for field density tests.
Scales, railway, fandial, triple beam and balance.
Sample tins.
Moulds for test blocks.
Trays for sample drying.
Moisture content tester such as "Speedy".
Saybolt-Furol Viscometer.
Ring and Ball apparatus.
Penetrometer for Tars and Bitumens.
Flash Point (Cleveland Open Cup).
Standard Tar Viscometer.
Standard Tar Distillation apparatus.

Minor equipment such as thermometers, timers, scoops, glass and rubber tubing, beakers, measuring jars, hydrometers, etc.

considerably within themselves. Provided the engineer in local charge of sealing work is satisfied that the sealing medium conforms to the specification in its important physical properties, there is little more that he can do without a comprehensive analysis. It is when the tests carried out by the local laboratory give cause for concern that a more thorough investigation is necessary. The district laboratory should confine its testing to such things as penetration, viscosity, softening points and flash point for tars and bitumens with the added test of distillation for tar and cutbacks.

As far as research is concerned, I do not think that this is a major function of the district laboratory, and should only be undertaken at times when routine testing is not required. Such research should be limited to trials of different methods of constructing metal courses, new sealing techniques and so on, laid on short stretches of highway within easy reach of the laboratory. Generally speaking the district laboratory will not have much time for this research work which is probably better handled by a central laboratory. Valuable information can, of course, be gained from any work that districts find time to do, and I do not deprecate any attempt along these lines, but not at the expense of the routine investigation and testing, which is the district laboratory's primary function.

test pits. If sufficient coverage of the working site is given by any or a combination of these methods, the laboratory can provide the engineer with a reasonably accurate picture of the conditions likely to be encountered when construction begins. Valuable preliminary information can also be obtained on bearing values by use of the hand driven penetrometer. This information can later be confirmed and augmented by tests taken with a C.B.R. apparatus.

Once construction has started, the testing of materials for use in the structure should be undertaken. Mechanical analysis of soils, aggregates and metal, physical properties of soils encountered in cuts and used for fills will all be necessary. This latter point is especially important because the future stability of the road structure is only as good as the material which makes up the foundation. Therefore rigorous testing of fills by means of field density tests should be an automatic function of the laboratory. The laboratory should also be able to advise on the optimum moisture content for any material used in a fill and the best compaction procedure to be used.

For bridges and other concrete structures, selection of a suitable aggregate source, and design of a mix to give the requisite strength combined with economy of cement, are tasks which the laboratory should be able to cope with. As a follow-up to this, checks on the concrete being used in the structure must be made regularly. These checks will normally be confined to compression strength and density.

From tests carried out on metal sources in the area, including abrasion, mechanical analysis incorporating testing for clay or organic matter, the engineer can decide on the best source for metal, and by regular testing the laboratory can ensure that the metal complies with the specification. Should any one source not provide a satisfactory product, the laboratory should be capable of advising on measures to make the metal on the road comply with the specification, either by addition of material from another source, or further treatment of the original product.

With much of the sealing work on roads being done by contractors, it is important that regular checks be made on the physical properties of the sealing mediums used. Generally speaking all shipments are sampled and tested in a comprehensive manner at the Dominion Laboratory, but it is still necessary to carry out local testing, as shipments of materials can vary

MINIMUM REQUIREMENTS FOR A DISTRICT LABORATORY DEALING WITH ROADING

By J. E. C. Pollock

When writing on a subject like this, it is difficult to avoid making a catalogue of items and writing explanatory notes about each one. In an attempt to make this article other than a catalogue, I have listed the equipment considered necessary in an appendix, and will treat the subject in a general way.

The district laboratory and its staff must be considered as an integral part of the roads organisation in a district office. Upon its functioning as an adequate, efficient testing and limited research unit, depends much of the success of the road and bridge building programme in the area. No highway or design engineer should embark on a construction job unless he is satisfied about the foundations on which the structure will be built, or that the materials which he proposes to use in the structure, are adequate for the purpose. This can be considered the task of a district laboratory and its staff to provide the information which will enable the engineer to produce a materially sound structure, whether it be road, bridge, culvert or other road unit.

Staffing of the laboratory is an important point, and this has been realised in recent years by the improvement in status, financially and otherwise, of the officers who run and work in the laboratories. In districts the average staff should consist of a senior technical officer or technician in charge, with at least two assistant technicians. Additional staff in the way of one or two skilled labourers, will also be necessary at certain times. The staffing of a laboratory will vary from district to district, but I have given what I believe should be an average.

It has previously been mentioned that an engineer requires to be satisfied about the foundations on which his structure will rest. This then must be the first task which the laboratory should be capable of undertaking, the investigation of foundation materials and the strata immediately underlying the actual foundation material. Much information can be obtained by the engineer from geological maps and from geologists, but local irregularities in the formation will only be discovered by detailed investigation. Several methods are available for this investigation, and those which should be performed in districts include core drilling, auger holes and

COMMENT

By F. M. Hanson

In some areas of New Zealand there are local materials which would provide a foundation even better than pumice so that when covered with a metal topcourse one stone thick, say 2", and capped with 1½" of hot mix asphaltic course, a very satisfactory highway from a technical point of view would result. The choice of treatment, however, would have to stand up, of course, to cost analysis.

If cost and availability have no bearing on the grading of aggregate the usual bituminous concrete grading up to 3/4" in size will provide a very satisfactory 1½" carpet. However, a mix can be designed to meet gradings outside that usually specified. For instance, the Taupo lakeside grit was somewhat water worn and even with pumice added as filler the grading was deficient.

The type and grading of the aggregate will to some extent determine the bituminous binder to be selected, but this will usually be straight 180/200 or 80/100 penetration. A binder which will give sufficient initial stability should be selected. For this reason 180/200 penetration is generally to be preferred where the pavement will not be subjected to other than pneumatic tyred traffic.

One important advantage of this type of work is that there is a longer paving season than for road oil sealing. Conditions must be dry but air temperatures down to 50°F are quite acceptable.

If it is thought that local conditions are right for hot mix asphaltic surfacing of any particular road, the matter should first be discussed with Head Office before a final decision is made.

the purpose of the discussion it serves to give a comparison of costs to be expected for work of any magnitude in the Mihi area. North of Mihi the increased costs of carting Taupo grit result in the asphaltic surfacing being more expensive than metal and 2 coat seal at Waiotapu where the unsealed Rotorua-Waikaremoana S.H. joins the Rotorua-Taupo S.H.

In the Rotorua-Whakatane area, Rotoma rhyolite for the asphaltic mix would have to be used as has happened in the past. Since the material for the asphaltic mix has to be quarried, the costs are therefore much higher and with the opening up of various quarries east of Rotoma would not now be an economic proposition.

In the foregoing examples the costs of metal and sealing chips are based on recent prices from the quarries concerned. The cost of asphalt assumes a binder content of 16 gallons per cubic yard and a 33-1/3rd per cent allowance has been made in cartage to the drying and mixing plant on the site to allow for bulking and compaction. The quantity of asphalt required has been based on a coverage of 5 tons per 100 sq. yds 1" thick, 1 cu.yd. being assumed to weigh approximately $1\frac{1}{4}$ tons.

All the major State Highways in the Rotorua-Taupo area have now been sealed, the two exceptions being the Rotorua-Waikaremoana and Taupo-Napier State Highways. The comparisons of costs given show that the asphaltic carpet type of construction on $2\frac{1}{2}$" of metal is an economic proposition in the latter case.

It has been mentioned that the asphaltic carpets carried out since 1950 using Taupo grit are in good condition, and they have many years of life ahead of them if properly maintained by resealing (as for any other type of sealed road). These carpets have been laid on a pumice formation, whereas the costs have been taken out on a substantial metal course which must result in a much greater strength.

In conclusion, it would appear that when any further sealing of new road construction works in the Taupo area is being carried out, consideration must be given to the use of a hot laid asphaltic carpet on a $2\frac{1}{2}$" metal course. If any reduction in the depth of this metal course is possible, this proposition becomes very attractive from an economic viewpoint.

The foregoing shows that the cost of the 1½" asphaltic mix on a 2½" metal course is slightly cheaper than the conventional metal and two coat seal, even though the example chosen is close to a quarry.

A two mile deviation will be required to be constructed shortly in connection with the new Waikato River bridge at Mihi on the Rotorua-Taupo State highway. Mihi bridge is 28 miles from the Taupo grit deposit and the nearest and cheapest source of road metal is a river worn greywacke at Murupara 39 miles away. A comparison of costs in this case is as follows:-

1. Metal and 2 Coat Seal (per chain 20' seal)

Metal on road	40 c.yd.	@ 54/-	£108. 0. 0.
Construction of metal course per chain		£15	15. 0. 0.
Preparation of surface	147 sq.yd.	@ 2d.	1. 4. 6.
Tar	50 gals.	@ 4/6	11. 5. 0.
Sealing chip	2¼ c.yd.	@ 75/-	8. 8. 9.
H.R.O.	58 gals.	@ 4/6	13. 1. 0.
Sealing chips	3 c.yd.	@ 75/-	11. 5. 0.
	Cost per chain		£168. 4. 3.

2. Metal and 1½" Asphaltic Carpet

Metal on road	20 c.yd.	@ 54/-	54. 0. 0.
Construction of metal course		@ £9	9. 0. 0.
Preparation of surface	147 s.yd.	@ 2d.	1. 4. 6.
Primer	37 gals.	@ 4/6	8. 6. 6.
Grit coat	¾ c.yd.	@ 46/-	1.14. 6.
Tack Coat	15 gals.	@ 4/6	3. 7. 6.
Asphaltic mix	7½ c.yd.	@ £7.7.0	55. 2. 6.
Cart and spread	7½ c.yd.	@ 4/6	1.13. 9.
Place and compact	7½ c.yd.	@ 7/-	2.12. 6.
Seal coat (emulsion)	30 gals.	@ 4/-	6. 0. 0.
Grit	¾ c.yd.	@ 46/-	1.14. 6.
	Cost per chain		£144.16. 3.

In this case, where the road metal source is some distance from the job, the additional cartage costs result in a relatively greater increase in cost in the case of the metal and 2 coat seal than the asphaltic mix, since the quantity of crusher run products required is greater.

This latter example is perhaps not realistic in that for such a small isolated length of road the costs of setting up the asphalt mixing and drying plant would be exorbitant, but for

With attention to compaction on a new formation and using suitable pumice, C.B.R. tests of between 40 and 50 are attainable without much difficulty. For Class II loading a metal depth of 4 to 5 inches is required (see Mr Hanson's paper "Relationship of Metal Depths and Subgrade Properties for Modern Highway Loads") and it is now the practice in the Rotorua-Taupo pumice area to provide a 5 inch compacted metal course on all new construction works. For comparison purposes, and in view of previous remarks, it will be reasonable to allow for a half metal course (2½" compacted thickness) and 1½" of hot mix for the asphaltic course.

Within the next few years the Rangitaiki Plains-Tauhara section of the Taupo-Napier State Highway will probably be reconstructed and sealed. This section is 15 miles from a good greywacke quarry and 12 miles from the Taupo grit deposit required for the asphaltic mix. On present day costs the comparative estimates for 20' wide metalling and sealing or surfacing one chain of road are as follows:-

1. Metal and 2 Coat Seal

Metal on road	40 c.yd	@ 30/-	£60, 0. 0.
Construction of metal course	per chain	£16	16. 0. 0.
Preparation of surface for sealing	147 sq.yd.	@ 2d.	1. 4. 6.
Heavy sealing tar	50 gals.	@ 4/6d	11. 5. 0.
Sealing chip	2¼ c.yd.	@ 55/-	6. 3. 9.
Heavy road oil	58 gals.	@ 4/6d	13. 4. 0.
Sealing chips	3 c.yds.	@ 55/-	8. 5. 0.
	Cost per chain		£116. 2. 3

2. Metal & 1½" Asphaltic Carpet

Metal on road (1/2 course)	20 c.yd	@ 30/-	30. 0. 0.
Construction of metal course	per chain	£10	10. 0. 0.
Preparation of surface for priming	147 s.yd.	@ 2d.	1. 4. 6.
Primer (MC_2)	37 gals.	@ 4/6	8. 6. 6.
Grit coat	¾ c.yd.	@ 30/-	1. 2. 6.
Tack coat	15 gals.	@ 4/6	3. 7. 6.
Asphaltic mix at dryer	7½ c.yd.	@ £6.3.0.	46. 2. 6.
Cart and spread	7½ c.yd.	@ 4/6	1.13. 9.
Place and compact	7½ c.yd.	@ 7/-	2.12. 6.
Seal coat (emulsion)	30 gals.	@ 4/-	6. 0. 0.
Grit	¾ yd.	@ 30/-	1. 2. 6
			£111.12. 3

It has previously been mentioned that the Te Ngae-Rotoma and Mihi-Wairakei sections are in very good condition. The question can be asked as to why they should be so much better than the Motuoapa-Taupo section which is only a little older, in one case at least the materials used for the asphaltic mix being the same. In the previous paragraph an opinion was given as to the causes of the deterioration in the Waitahanui-Taupo section in particular. Complementary to this explanation, it is suggested that the reasons why the lengths surfaced since 1950 are so much better are:-

(a) The surfacing was applied on a newly constructed formation with good alignment, shape and drainage.

(b) The pumice formation was well compacted with modern earthmoving machinery, the need for better and closer control of plant being more fully appreciated.

(c) The surfacing was mixed, laid and compacted with more modern and efficient pavers than originally used.

(d) Experience by contractors and Departmental labour has resulted in better construction techniques.

Now if it is accepted that a $1\frac{1}{2}$" thickness of hot laid asphaltic mix on a well compacted pumice foundation is capable of carrying Class II traffic, and experience on the Mihi-Wairakei and Te Ngae-Rotoma sections shows that it does except for an occasional weakness on the shoulders due to inadequate horizontal shear strength of the pumice formation, then it is logical to assume that with the addition of a light metal course not only will greater strength be achieved but any tendency for the shoulders to squeeze out will be eliminated due to the increased resistance to horizontal shear. It might be added that the mosaic surface of such a metal course would give a much improved surface on which to apply the priming coat prior to the application of the asphaltic carpet.

With the National Roads Board's numerous commitments, it is unlikely that funds will be available for the letting of very large crushing contracts as in 1956 in the Rotorua-Taupo area, it being considered more likely that road metal and chips will be supplied on a smaller scale for reconstruction and sealing works of a definite length rather than stockpiling materials for use over several years. This being the case, it would be instructive to compare the present day costs of a hot laid asphaltic carpet and the conventional metal and two coat seal type of construction.

Taupo, while the remainder although still comparatively good cannot be compared with the Mihi-Wairakei and Te Ngae-Rotoma sections.

Although the Motuoapa-Taupo section was the first length to be surfaced, the reason for its more rapid deterioration cannot be attributed to its greater age since this only amounts to two or three years. Further enquiries and investigations, however, reveal the following facts:-

(1) The Waitahanui-Taupo section has deteriorated not only on the shoulders but in many places over the whole surface, the surface being crazed and out of shape.

(2) The Motuoapa-Waitahanui section while considerably better shows similar failures on the shoulders only with one or two minor exceptions. Long sections are in excellent condition indicating that there is no fault in the asphaltic mix itself.

(3) The Waitahanui-Taupo length is on a generally poor alignment and was in effect surfaced "as is" after some reshaping. The depth of asphalt will probably vary considerably.

(4) While the Motuoapa-Waitahanui length is on a comparatively good alignment, it is only 18 ft in width.

(5) The nominal depth of asphaltic mix was 1 inch as opposed to the 1½" provided on all other similar surfacings elsewhere.

From a study of the foregoing points and an inspection of the road itself the conclusion has been reached that deterioration has been due to a combination of inadequate depth of asphaltic material in places, insufficient compaction of the formation prior to surfacing, and insufficient horizontal shear strength of the pumice formation to prevent squeezing out of the shoulders, this fault being accentuated by the narrow seal causing a high percentage of traffic to run near to the edge of the surfacing. With regard to this latter point, it is significant that in general the few minor faults which have occurred on the Te Ngae-Rotoma and Mihi-Wairakei sections are on the shoulders, and it is believed that insufficient horizontal strength of the pumice formation is solely responsible.

(a) Between 1950-1955 on the Te Ngae-Rotoma Hill section of the Rotorua-Whakatane S.H. (Rotoma rhyolite).

(b) Between 1950-1954 on the Mihi-Wairakei section of Rotorua-Taupo S.H. (Taupo grit).

(c) Between 1947-1950 on the Motuoapa-Taupo section of the National Park S.H. (Taupo or Motutere) grit.

A further length was laid on the Waiotapu area on the Rotorua-Taupo S.H., but this has deteriorated since the area traversed is thermal and foundations were generally very poor. This length cannot therefore be taken as a representative example of hot laid asphaltic surfacing laid in the Rotorua-Taupo area, and it is proposed therefore, to confine further discussion to the three main lengths enumerated in (a) to (c) in the foregoing paragraph.

Before describing the present condition of the surfacing it would be as well to describe in broad outline the form of construction used. Briefly, all the lengths concerned consist of a pumice formation primed generally with MC_2 and grit or pumice. Onto this primed surface the asphaltic mix was applied and compacted by a paving machine and roller after application of a tack coat, the thickness being $1\frac{1}{2}$" with the exception of the Motuoapa-Taupo section where the depth was reduced to 1". On completion of the hot laid asphaltic carpet an emulsion and grit waterproofing coat was applied either immediately or within 12 months. The materials used for the Mihi-Wairakei and Motuoapa-Taupo sections were Taupo or Motutere grit with the addition of a suitable pumice filler, whereas on the Te Ngae-Rotoma section use was made of a quarried rhyolite from Rotoma crushed from 3/4" down. It should be noted that in general no metal course was used whatsoever, the asphaltic carpet being laid on a compacted and primed pumice formation.

A recent inspection of the lengths under consideration show the Te Ngae-Rotoma (1950-55) and Mihi-Wairakei (1950-1954) sections to be in very good condition, apart from a few localised failures, there being no appreciable difference in the quality and durability of the asphaltic material manufactured with Taupo grit or Rotoma rhyolite. In the case of the Motuoapa-Taupo length (1947-1950), a deterioration has taken place over half its length - namely Waitahanui to

THE USE OF HOT LAID ASPHALT MIX IN THE ROTORUA-TAUPO PUMICE AREAS

By P. F. Reynolds

The Rotorua-Taupo pumice country is notoriously short of sources of good quality road metal suitable for use as base-course or for sealing chips. Some years ago this led to investigations into the use of alternative methods of producing a satisfactory sealed surface using local materials not otherwise suitable for conventional metalling and sealing as generally carried out in New Zealand.

As a result of mix in place experiments carried out on trial sections of road over a period of years using various local materials, it was found that two or three deposits of metal were suitable for use in the manufacture of bituminous concrete. These deposits are to be found on the shore or adjacent to the lake south of Taupo at Motutere, and also near the lakes in the Rotorua area. In the former case the deposits consist of rhyolite and obsidian particles ranging between 1/4" and 1/8" in size, whereas in the latter case the deposits consist of a soft rhyolite rock which must be quarried and crushed before use. There were various other metal deposits which were investigated, notably a good river worn greywacke at Murupara, but owing to the cartage and crushing costs involved they were not considered an economic proposition at that time since the roads to be treated were situated some distance away.

Short lengths of mix-in-place bituminous concrete were laid prior to 1947 with some success notably on the Rotorua-Taupo State Highway, one of the main difficulties being to obtain the specified thickness with a grader and to maintain this during rolling.

During 1947 suitable heating and drying plant became available together with a self-propelled paving machine which had just been imported by a Contractor. As a result, a contract was let for the manufacture and laying of a hot laid asphaltic mix on the National Park-Taupo State highway using the local grit deposits adjacent to Lake Taupo. Between 1947 and 1955 over 75 miles of hot laid asphaltic mix were laid on State highways in the Rotorua and Taupo area using Taupo grit or Rotoma rhyolite in three main lengths, namely -

In a few other places there had been local disintegration in small patches. The total area affected at present is about 3,000 sq.yds in a total area of motorway carriageway of about 280,000 sq. yds.

Several trial holes have been opened up in the damaged portions and excess moisture has been found lying in the tarmacadam base course, in the waterbound macadam and in the top of the shale from which it was seeping slowly at the edges of the carriageway. There has also been seepage from the ash layer overlaying the clay formation, but it is not clear whether this is associated with the conditions of the upper layers.

From the preliminary investigation it appears that most of the excess moisture in the ash layer has been held in from the construction period and that the excess moisture in the upper layers was probably partly trapped during construction though some may have entered through the surface.

It seems likely from a first examination, which has been hampered by further conditions of frost, that the surface defects which have occurred were due to the presence of this excess moisture in the base courses which also showed at the top of the shale. Final conclusions cannot be drawn until there has been a period of continuous thaw.

The first and most urgent task is to drain the places where there is excess moisture and this will be done by a system of longitudinal rubble drains along most of the length of each edge of each carriageway, connected to the existing drainage system. Provision will be made for draining the upper courses in places by cutting slots in the concrete marginal strips. This will be followed by the reinstatement of the base and surfacing where it has failed.

and spaced at intervals to correspond with the amount of unconsolidated metal available on the surface. The grader does this work quickly.

With transverse metal hurdles, overtaking is out of the question and a stream of traffic is forced to travel at the speed of the slowest vehicle. Hence the effective consolidation.

Metal consolidation, in the rounded Hawke's Bay metals at any rate, can be effected only if the surface beneath is hard. The iron tyred roller must have a hard surface beneath the metal if compaction is to be cheap and quick. If this condition is not met the open metal surface will not choke. Each lift of metal of 4" loose depth should be consolidated and unyielding before the next layer is applied.

COMMENT

By F. M. Hanson

There is a tendency to look upon "Overlay" as a cure for all road ills. In some districts this technique is being used to overcome a "fatty" bituminous surface. It is sometimes used merely as a smoothing coat. In other cases it has been used to upgrade the load classification when there was no evidence that the existing road would not adequately carry heavier loads, and in many cases the layer of 9 to 12" of high class expensive metal has been used when 6 or 7" of cheaper sub-base material covered with 3 or 4" of high class metal would have given equally good results at a much lower cost. "Overlay" is not a substitute for plant-mix smoothing of a sound but rough road.

Road faults must be properly diagnosed before "Overlay" is decided upon and sound engineering judgment must be exercised in determining the thickness of "Overlay". Roads which are showing serious failures because of plastic topcourse binders should as a general rule be treated with "Overlay". Strengthening of the older roads which have only a few inches of metal on weak subgrades, building up depressions which become submerged in wet winter months, making good low or falling-away superelevations, correcting roads over swamps or similar foundations where the cross section is so bad that several inches of correction are required, are all cases where "Overlay" would be a logical choice of treatment.

Except where the existing bituminous surface of the road to be treated is tight and waterproof, I do not agree with the development in the Napier district of omitting the initial coat of tar or bitumen and it is believed that bitumen is preferable to tar for this purpose. The film of bitumen of 80/100 penetration for preference will bind up the old surface and will form a waterproof skin which will tend to shed compaction water or heavy rain which is difficult to prevent from penetrating or soaking down through the metal. Also, of course, as stated by Mr Neale, the tightening up of the old seal does help in preventing clay working up through the old road into the "Overlay".

Many roading authorities in countries other than New Zealand have found the benefits of a waterproof membrane at the bottom of the metal course in clay country. If the underlying subgrade is granular then the membrane is not so

necessary for in this case the subgrade is simply what in other areas would be accepted as non-plastic sub-base. Such conditions obtain in pumice regions, in the sandy areas of the North Island West Coast, in the gritty volcanic soils of Taranaki and, of course, many of the subgrades of Canterbury and other South Island areas are completely granular and non plastic.

In the case of the highly plastic clays of the North Auckland and Northland areas, it would be advantageous to apply the bitumen membrane even in the case of new road construction. A few inches of the cheapest grade of metal available, notwithstanding that it may be somewhat plastic, could be spread over the clay subgrade perhaps as a temporary metal course for construction traffic and the bitumen membrane could well be applied to this temporary metal layer just prior to the normal sub-base and metal course construction. It is generally not practicable to apply a bitumen membrane direct on a clay subgrade; hence the use of the temporary metal layer.

Mr Neale has rightly called attention to the problem of compaction water. He has found the weakness of the ordinary sprinkler system and I commend his suggestion for some form of pressure application to give a fine mist. Providing that there is no heavy rainfall before some degree of compaction has been achieved, then the fine mist may allow of compaction without water soaking down into the road foundation.

As was done by Mr Keller, Mr Neale mentions the metal grading and the lack of fines. I referred to this in my comment of Mr Keller's paper in this series. It is often necessary to produce fines by a second crushing of some fraction of the metal. It is a very expensive expedient to use rollers and other compaction equipment to break down metal to give the required fines.

At this stage of roading in New Zealand there is a very definite place for "Overlay" to correct deficiencies especially in the older roads, but care should be exercised to ensure that there is not a cheaper but equally serviceable answer to the particular problem.

DESIGN AND USE OF PLANT MIX SMOOTHING COURSE WITH PARTICULAR REFERENCE TO SOFTER STONE OF TARANAKI

By W. A. Scott

1. DESIGN

The object is to produce economically, a graded aggregate mixed with a bituminous binder that will give a reasonably dense plant mix that can be laid cold and will compact down without being picked up by traffic.

As with concrete some things in the mix are critical. For instance, the amount of binder must be controlled because if there is too little the mix will not bind and if there is too much a fatty surface will result. However, I think it better to err on the high side as if the surface does show fatty this can be blotted up, but if there is not enough binder very little can be done to remedy the trouble. The mix is fairly sensitive to materials passing the 200 mesh sieve and if this is not available naturally then it will pay to add say cement as a filler. I think a crushed aggregate and sand is best but with the vesicular aggregates available round Mount Egmont a mix can be made using say 50% of each.

When starting to use new sources of supply the best way is to make a stab and make trial mixes adjusting as required to get a suitable product for the conditions existing.

Because the raw material is comparatively soft round Taranaki - a Los Angeles loss of 40% - 50% - the aggregate fed into the dryer and mixer should be coarser graded than for a harder stone. This is because a certain amount of breaking and abrasion takes place during the drying and mixing processes.

Because they are vesicular Taranaki aggregates require a bit more binder to coat them than a harder stone such as greywacke. This is because some of the binder is absorbed and plays no part in the binding of the particles.

A typical mix for Taranaki stone is as follows:-

Passing 3/8" square mesh	100% by weights
Passing 1/4" " "	70% " "
Passing No. 8 B.S.S.	45% " "
Passing No. 52 B.S.S.	25% " "
Passing No. 200 B.S.S.	10% " "

Using heavy residue $SC_{3/4}$ this took 6.25% of binder by dry weight.

The limits for local stone are:-

Passing 3/8" square mesh	100%
1/4" " "	65% - 75%
No. 8 B.S.S.	40% - 50%
No. 52 B.S.S.	20% - 30%
No. 200 B.S.S.	5% - 15%

The aggregate must be quite dry before mixing with the binder and batching should be accurate.

Depending on factors such as weather, capacity of plant, traffic, thickness to be laid and the individual's preference, there are several choices of binder. The three main ones are:-

1. Asphaltic MC_3.
2. Road Oil MC_3.
3. Heavy Residue $SC_{3/4}$.

Asphaltic MC_3 may be produced by fluxing 80% of 80-100 penetration bitumen with 20% of power kerosene. This is a suitable binder only when plant mix is to be laid straight from the mixing plant. It is particularly useful if weather is not dependable or for doing a special piece of road that has a traffic problem. To do long lengths a good set up is needed to keep the supply up to the laying gang. Road oil MC_3 may be produced by fluxing 87½% of medium road oil with 12½% of power kerosene. This is a slower curing binder than MC_3 and allows more time for laying off. It can be stockpiled in compact heaps for short periods. This is not used in Taranaki as far as I know.

Heavy residue $SC_{3/4}$ may be produced by fluxing 80-100 penetration bitumen with fuel oil in proportion 72½% bitumen and 27½% fuel oil. The plant mix made with this binder can be stockpiled for months if required. This gives it advantages over other binders, for example:-

1. A small capacity plant can be used to do a large job.
2. A smoother finish can be got because more time is available to work the mix.
3. It can be transported long distances by rail if required.

It also however, has one big disadvantage and that is that its slower curing properties make the mix vulnerable to rain damage. However, given a couple of reasonably warm days the risk is negligible.

Light medium and heavy furnace oils would be suitable for fluxing depending on how long it was intended to keep the plant mix stockpiled.

2. USE OF PLANT MIX SMOOTHING COURSE

Taranaki plant mix smoothing course is used to improve the riding qualities of old badly shaped carriageways. It has been used most effectively to correct camber after some of the old high cambered roads have been widened by shoulder counter sinking. It is impossible to mate the old with the new and the plant mix irons out the difference.

The 3/8" down smoothing course is not suitable for filling deep irregularities unless these are done in stages; as a general guide 1" consolidated depth only should be the aim. If there are deep irregularities these should be taken out roughly first using a 3/4" maximum size aggregate and RC_5 or even RC_6 binder. This has to be laid hot and sets up immediately. An easier filler can be made with an SC_5 and 3/4-1/8" aggregate; this can be stockpiled and used cold on a warm day. However, before placing plant mix smoothing course over it the SC_5 mix must have been given time to mature out. Depressions up to 4" can be taken out with this SC_5 mix.

Although plant mix smoothing coats can be laid off quite well with a grader a multi bladed planer is superior. Pneumatic tyred compaction is first class and this combined with repeated blading will normally give a first class job.

3. PREPARATION FOR LAYING

Preparing the road for the mix is important. Plant mix is not suitable for repairing the road. Consequently potholes should be repaired (3/4" "no fines" SC_5 would be suitable provided it was done early enough for maturing and sealing off) and all surface cracking should be treated with asphaltic MC_2 again leaving enough curing time. In other words the smoothing course should not be asked to play any structural part in the carriageway but only smooth out the uneven structurally sound surface.

Having got a reasonably sound surface this should be swept clean as for a reseal and immediately prior to placing the plant mix a light application of say, asphaltic MC_3 made. Between 1/15 and 1/20 of a gallon per square yard should be enough as a tack coat to bind the mix to the road. For convenience quick breaking emulsion may be used as a tack coat if heating facilities are not available.

Plant mix is not waterproof and it is essential to seal the surface at the first available opportunity after it has matured. Because of this I do not think the hardness of the stone has much to do with the usefulness of plant mix; the job it is doing is taking out bumps and it is not a wearing surface.

COMMENT

By F. M. Hanson

The most important aspect of Mr Scott's paper is that it shows that smoothing plant mix can be successfully produced from quite inferior aggregate. I would add one or two suggestions which may help in developing a sound practice.

Mr Scott comments that if there is insufficient bituminous binder in the mix there is little that can be done about it. It is agreed that a mix lacking in binder will not bond down but I believe this can be overcome by spraying lightly with emulsion and sanding. After the mix has been laid off with the grader it may be possible to operate over the surface a pneumatic tyred vehicle or an orthodox roller. If such is the case this should be done and then the mix should be sprayed with emulsion and sanded. Rolling or pneumatic tyred compaction should then be continued. If the mix is disturbed too much by any compacting methods after it is laid off by the grader or planer, the emulsion and sand should be applied immediately without any preliminary rolling.

A mix deficient in aggregate fines will behave somewhat like a mix which is lacking in bituminous binder. Mr Scott suggests overcoming any shortage of minus 200 mesh material by adding cement. The addition of cement or limestone dust to a hot bituminous concrete mix has sometimes to be accepted but I believe it is preferable to avoid cement in cold laid smoothing plant mix. Cement has a tendency to harden bituminous mixes and therefore would be better kept out of our smoothing type of plant mix. A limited deficiency of fines in a cold laid plant mix can usually be remedied by an application of emulsion and sand. This will bond and tighten the mix as with the emulsion/sand on the mix with a bituminous binder shortage.

If a plant mix is being laid merely as a thin smoothing course on a sound but bumpy or rough bituminous surface, I do not think there is usually a need for a seal coat. The emulsion/sand seal is only necessary to bind the plant mix together when there is either a deficiency or bituminous binder or a shortage of aggregate fines.

In earlier years it was thought that quicker setting binders of the MC variety would be preferable for plant mix when it was to be used in areas where the weather is not too favourable for bituminous work. Experience has shown, however, that Heavy Residue $SC_{3/4}$ meets weather conditions almost as well as other bituminous materials and $SC_{3/4}$ has so many other advantages that for the future this binder should be the normal practice.

The 72½% of 80/100 bitumen plus 27½% of fuel oil which Mr Scott uses for the production of his Heavy Residue $SC_{3/4}$ is slightly at variance with the best average practice in other districts with other aggregates. The bitumen and oil mixture which best serves average conditions was set out in my report on "Roading in Tasmania" on Page 131.

Under cooler weather conditions or for a particularly dense aggregate, or when stockpiling for long periods of weeks or even months, then the softer material produced by 68% of 80/100 bitumen plus 32% of fuel oil will probably be the most satisfactory. Otherwise 70% of bitumen should generally not be exceeded.

Almost any very lightly applied bituminous binder will serve as a tack coat but I believe the tendency today is to use emulsion probably because of its convenience in handling, preparing and spraying.

Plant mix has a variety of uses in the construction and maintenance of both highways and aerodromes and it will be advantageous if local aggregates can be accepted. Engineers therefore should ascertain the possibilities of their cheaper local aggregate supplies when considering the production of cold laid plant mix.

THE PROBLEM OF SEALING WHERE ONLY WET CHIPS ARE AVAILABLE

By P. M. Newby

In all Districts there will be occasions where the chips available for a particular seal are wet, either because they have been delivered straight from the washing plant or the stockpile has not dried out.

In the former case, unless prior precautions have been made, the best course will be to abandon sealing and stockpile the chips to dry out. However, both in this case and the case where the stockpiles are wet, sealing should be satisfactory provided the weather is hot and sunny, the chips are spread on the road directly behind the sprayer and they dry on the road within five minutes of application.

The summer months in most parts of New Zealand are sufficiently hot and fine to make it possible to carry out sealing without any special precautions for wet chips or wet weather. However, in the higher rainfall areas, and towards the end of the season, some precautions may be necessary. Suggested methods for dealing with this problem are:-

(i) Concentrate sealing during the limited fine periods.

(ii) Cover stockpiles.

(iii) Use additives.

(iv) Precoat chips.

(v) Apply emulsion seal on chips.

Dealing with these in detail -

(i) Concentrate sealing during the limited fine periods

This is perhaps the most convenient method but requires good organisation and the provision of a larger than otherwise plant set up with a comparatively large amount of standing time.

(ii) Covered Stockpiles

This is an effective way of combating the problem of wet chips. The cost of permanent installation would be uneconomical for normal second coat and reseals but as a temporary expedient, using tarpaulins, this method has been used to good advantage.

(iii) Additives

Three methods of application are used:-

(a) Pre-treatment of the stone chippings.

(b) Sprinkling the additive in the binder film.

(c) Incorporation of the additive in the binder before spraying.

Method (c) is the most commonly used because it is the most convenient.

The use of additives would give good results for damp chips and would minimise the detrimental effect of rain or cold weather soon after sealing. However, it is doubtful if it would give satisfactory results with "dripping" chips.

Doumeen T and Stearine Amine are the only two additives recommended with additions of 1 to 2% by weight.

The additional cost is approximately 3d. per gallon.

(iv) Precoating of Chips

Provided chips can be obtained dry or, alternatively, mechanically dried, precoating with an extra light primer tar is a practical though comparatively expensive alternative. Approximately 2 gallons per cubic yard would be required and mixing could be carried out in a standard concrete mixer.

(v) Emulsion Seal on Chips

A method which has proved effective in checking whip off of chips is to spray a light quick breaking emulsion over the chips blinding with a 1/4" - 1/8" chip if necessary. This method would probably be effective also if sprayed on wet chips immediately after rolling, though no cases of it having been done are known to the writer.

COMMENT

By F. M. Hanson

As Mr Newby points out there are several methods of attack against wet sealing chips. If weather is dry and warm, chips will quickly dry out when applied to the road and usually no special precautions are required beyond the immediate spreading of the chips following the sprayer. On the other hand, if the weather is damp or showery and cool it is inviting trouble to use wet chips for road oil sealing. Indeed even dry chips under adverse weather conditions may not prevent "scabbing". Also loss of chips will frequently occur in the

case of road oil sealing at the end of the season.

Additives and precoating of chips will tend to assist adhesion, but particularly where there is a high traffic count these treatments will not prevent loss of chips. The simplest and most efficient method of ensuring adherence of chips under adverse conditions is to penetrate the chipped surface with a sealing emulsion immediately following the rolling. The emulsion is blinded with sand or grit. Even in this case if heavy rain follows before the emulsion has had reasonable time to set up it will re-emulsify and may be washed away. However, road oil sealing would not generally be undertaken when the weather was so threatening.

If the road oil had been applied at say, one-third of a gallon per square yard, and this amount was on the basis that the road oil would rise to two-thirds of the height of the chips, then theoretically it would require only another sixth of a gallon to cause the bituminous material to just reach the top of the chips. A sixth of a gallon of bitumen would be deposited by about one-third of a gallon of emulsion. It would thus seem that any quantity of emulsion less than one-third of a gallon would not cause flushing of the surface. A reasonable and practicable quantity to apply in this case would be one-fifth to one-quarter of a gallon.

The emulsion/sand coat does, of course, cost money, but it is not as expensive as a complete re-seal or a full plant mix remedial treatment following "scabbing". In districts where wet chips or adverse weather conditions obtain or when sealing is carried out towards the end of the season, it must be accepted as good practice to apply an emulsion/sand coat. This is not a theoretical approach. The method was well tried and proved as long ago as 25 years and it has been successfully adopted in some instances quite recently.

SEALED AREAS FOR PEDESTRIANS AND PLAY AREAS

By D. R. Lovatt

INTRODUCTION

Many sealed areas are used mainly by pedestrians. The usual chip seal used on highways is too rough for this purpose and some type of finely textured surface is required. This paper indicates the properties required of, and suitable methods for obtaining a good surface for pedestrian use.

The surface should be smoothly graded without sudden irregularities or humps and hollows, since accidents are more likely if these conditions exist, water will not drain away properly, and the finished work will be unattractive in appearance. The surface texture should be fine and sharp with no loose stone on top. Sharp sand undoubtedly produces the best non-skid surface. Gravel surfaces are particularly objectionable in school grounds where accidental falls occur more often. Sufficient crossfall should be provided to half-round channel, gutter or sump. The surface must be watertight since paths are just as susceptible to potholes and soft patches as are highways. Some areas, although used primarily by pedestrians are occasionally used by wheel traffic. For instance playgrounds are used as car parks and paths as drives. It is therefore essential that the subgrade and metal course should both be able to carry these exceptional loads without cracking. The areas may be tested before surface treatment by running over a test load. A five ton truck should not leave any marks on the prepared surface.

There are two other features which should be considered when selecting a surface treatment. Firstly the degree of inconvenience and disruption during the laying of the surfacing, both to pedestrians who may be wanting to use the area, and also to those who own property in the vicinity. Careless spraying near buildings has necessitated repainting after a considerable waste of time and money in removing spots and strings of tar. The process should be done at low temperatures, and in still weather. Secondly, the ease with which repairs can be made when the surface has been disturbed during the laying or repair of underground services should be considered. Footpaths are often crossed by drains and telephone cables after some years of service and before treatment is needed.

More often than not the repair seal over these excavations is different from and not level with the adjacent surface. In places which are likely to be disturbed at some future time it is therefore desirable to lay an easily repaired surface.

There are many places where Portland cement concrete paths and paved areas can be used. Before using this material, it must be compared to a bituminous seal on all the above points. Irregular joints, cracks through overload and repairs after excavations are the greatest drawbacks in using concrete. There are, however, many places where the likelihood of disturbance is slight, such as steps, paths round houses and between buildings.

Bituminous sealing should be laid to a permanent edge of some durable material, viz. concrete, brick or stone kerbing, old rails or durable timber. If this is not done the edge will fret away or crumble under edge loading, weeds and grasses have greater opportunity to spread foots underneath, and this growth cannot be cleaned away without damaging the edge. The permanent edges also give a good screeding line or guide for control of the grading operations.

When new footpaths are being laid it is nearly always essential that weed killer be applied to the subgrade. It may also be required in the metal. Two types of weedkiller may be needed, one to kill tuberous rooted plants and the other for fibrous rooted plants. New types of weedkiller are being developed and a local expert or agent should be consulted.

The above general comments should be considered before embarking on a particular programme of area sealing. The job which is easiest and cheapest at the time of construction may within two or three years be an eyesore and a danger to the public. Repairing large areas and footpaths is a tedious job and inconveniences the public, and it is therefore recommended that only the most suitable type of seal should be used, not necessarily the cheapest.

There are a number of different ways of achieving a good surface. Some typical specifications for surfacing are given below. Also included are some clauses which apply to preparation of subgrade and metalling. No guide is given of costs but it should be remembered that plant mix can be produced when labour cannot otherwise be employed, whereas most other surfacing is produced on the job at the time of construction.

In areas where specialist firms are available to carry out particular jobs of area surfacing a simplified specification

stating material, quantities and end result required will be sufficient. The firm is not likely to jeopardise its good name by poor work, but a close watch should be kept and unsatisfactory work condemned. Small tasks can be done by Works Order but larger jobs will generally be let by contract. In both cases adequate supervision is essential.

PREPARATION OF SUBGRADE

The subgrade shall be brought to the required levels, grades and cross sections by grader or hand levelling with clean rotten rock or other suitable mineral material of low plasticity. The surface shall be rolled with a roller of effective weight in excess of 4 tons. In confined places or places with limited access, rollers of lesser weight may be approved. Any soft spots discovered during the rolling shall be replaced by good material. During and after rolling the surface shall be kept as near optimum moisture content as possible. The finished surface after rolling shall not vary by more than 3/8" from a 10 ft straight edge or camber board, nor should it be higher at any place than the specified level. Weedkilling treatment may be required at the direction of the Engineer (See Specification F1 1956).

METAL COURSE

Depending on the nature of the subgrade the engineer will direct the depth of metal course to be laid. It is unlikely that more than 4 inches finished depth will be required. In some instances the finished subgrade will be suitable with the addition of a dressing of fine crusher or other hard fine granular material. The metal course may be constructed of rotten rock, crushed or screened bank or river shingle, crusher run or other available material with reasonably low plasticity and good roadmaking qualities. The material must be carefully placed, bladed or raked to level, lean patches dressed with fines and the surface well rolled. Final dressing to level with additional fines may be required. The last operation on the surface before sealing is started must be rolling. A roller with an effective weight in excess of 4 tons is to be used except as otherwise specially approved by the Engineer. The finished surface shall not deviate by more than 1/4" from a 10 ft straight edge or camber board. All hollows are to be eliminated. Where a plant mix sealing is used the limits of accuracy may be lessened but no lesser depth than specified will be accepted. (See specification B3 1954).

SURFACING METHODS

Of the following methods of surfacing footpaths, the first four are accepted by the National Roads Board for subsidy purposes. The Board realises that higher standards of work are possible. (See Circular Memorandum 62/60/1 of 22 December 1958).

1. A first seal with either sealing tar or a $ROMC_3$ followed by an emulsion seal with a suitably graded sand covering.

2. A light tar primer coat followed by a mix in place course and finished with a double application of quick breaking emulsion and sand.

3. A light tar primer coat followed by a fine aggregate tar or bituminous macadam and finished with a quick breaking emulsion and sand seal.

4. A light tar primer coat followed by an emulsion penetration course blinded with sand and finished with a quick breaking emulsion and sand seal.

5. A light tack coat of extra light tar primer allowed to nearly dry and then covered with plant mix, raked and rolled. To be finished with emulsion and sand seal if considered necessary.

6. Emulsion squeegee coat of sand and slow setting squeegeeing emulsion for final finish on tennis courts and other high quality surfaces - this is a finishing treatment only.

7. Hot sand asphalt. This material is produced in specialized plants. As specifications and methods of production vary with the materials used and the type of plant, no specification is presented here. If this material is available commercially it can be used. The surface is first class but it must be laid quickly by experienced gangs.

Materials used in the methods outlined shall comply with Ministry of Works Specifications.

TARS, BITUMENS AND EMULSIONS

Light tar primer (LTP), extra light tar primer (ELTP), sealing tar and tar for tar macadam and plant mix - Specification M/2 1953.

Road Oil Medium Cutback 3 ($ROMC_3$), medium curing cutback 0 (MC_0), medium curing cutback 1 (MC_1), quick breaking emulsion slow breaking emulsion, slow curing cutbacks (SC_3) and (SC_4) and bitumen for bitumen macadam and plant mix - Specification M/1 1954.

MINERAL MATERIAL

All crushed mineral aggregate and chips shall be crushed stone of tough durable quality and all material shall be clean and free from dirt.

Grade C chips (3/8" nominal) for use with sealing tar and $ROMC_3$ - Specification M/6 1958.

3/8" mineral grit for use with light tar primer and extra light tar primer shall have the following grading: not less than 90% passing a 3/8" square mesh and not more than 10% passing a 1/8" sieve.

1/4" mineral grit for use with quick breaking emulsion shall have the following grading: not less than 90% passing a 1/4" square mesh sieve, not more than 15% passing a 10 mesh sieve, and not more than 5% passing a 50 mesh sieve.

Mineral aggregate 3/8" down for mix in place work shall have the following grading: passing 3/8", 100%; 1/4", 75 - 85%; No. 8 sieve, 15-35%; No. 52, 15%; No. 200, 0-5%.

Sand for use with slow breaking emulsion as a squeegee coat or for other blinding purposes shall be clean, free from dirt and conform to the following grading: Passing No. 10 sieve, 90%; No. 50, 15-30%; No. 100, 0-5%.

METHOD 1

Apply either a first coat tar seal in accordance with Specification P2 (October 1958) or a dust laying seal coat with $ROMC_3$ to Specification P3 (November 1954). Particular attention should be paid to spreading the Grade C chips and rolling them well as there will be no traffic compaction.

Allow the seal to set up for 3 weeks before proceeding with an emulsion and sand seal. The surface should be swept to clean off any loose chips or dirt which may have collected. The quick breaking emulsion shall be applied at an approximate rate of 1/4 to 1/5 gallon per square yard. Sand to the specified grading shall be uniformly spread and lightly broomed over the surface before the emulsion loses its chocolate colour. The sand must be thoroughly rolled in and any bare patches brought up.

The finished surface must be smooth and even in texture. It shall not vary by more than 1/4" from a 10 ft straight edge. Any hollows must be brought up to the required level with emulsion and sand and further rolling.

METHOD 2

This method was previously issued as Specification 51 (September 1946) and recommended for footpaths, yards and tennis courts. It is given here in fair detail as the individual coats may be used separately in different combinations of coats as set out in the other methods.

The following is a brief summary of operations:-

(a) Prime coat of 1/5 to 1/4 gallon per square yard.

(b) Mix in place course of 1/2 inch depth of 3/8 down mineral aggregate sprayed and mixed with 3/10 gallon per square yard of asphaltic MC_1.

(c) Penetrate the mix in place course with quick breaking emulsion at approximately 1/3 of a gallon per square yard and lightly blind with 1/4" mineral grit.

(d) Seal with quick breaking emulsion at the rate of 1/6 to 1/5 of a gallon per square yard and blind with a light application of sand.

Prime Coat

When the surface has been prepared to the standards previously defined and is sufficiently dry a prime coat of light tar primer shall be applied. Asphaltic primer MC_0 may be substituted with the Engineer's approval. The viscosity shall be adjusted to suit the weather conditions. The primer shall be heated and sprayed at a temperature not greater than 150°F nor less than 100°F. Primer shall not be applied when the air temperature in the shade is less than 60°F.

The primer shall be applied by an engine or hand operated sprayer at a pressure of not less than 25 lbs per square inch. Every precaution shall be taken to ensure an even distribution of primer. The rate of application should be between 1/5 and 1/4 of a gallon per square yard.

The smooth finish of the metal course must be preserved. If any damage does occur through movements of the sprayer or other equipment or by any other cause it shall be remedied before further priming proceeds.

The primer must be allowed to soak into the surface for at least 1 hour before proceeding with the mix in place course.

Mix-in-Place Course

After one hour and before four hours have elapsed 3/8" down mineral aggregate shall be distributed evenly to a depth

of 1/2" over the primed surface. Any unevenness in texture or level shall be corrected.

Asphaltic MC1 shall be sprayed over the aggregate at the rate of approximately 3/10 of a gallon per square yard. Light tar primer may be substituted for the MC_1. As the spraying proceeds the aggregate shall be hand raked, turned and drag-broomed until all particles are just uniformly coated but without an excess of binder. Where necessary to ensure even covering additional binder shall be added until an even texture is attained. Excess binder shall be absorbed by the addition of more aggregate. It is advisable to prepare a small stockpile of similarly treated aggregate for touching up the final surface.

When the mixture of aggregate and binder is to the approval of the Engineer it shall be screeded off, drag and hand broomed to a true surface of even texture and appearance. Additions from the stockpile shall be used to raise any low place. The surface shall be tested with a 10 ft straight edge and camber boards.

Rolling shall then commence with a roller weighing not less than 4 cwt preferably a heavier one. The surface shall be continuously rolled and tested to the accuracy of 1/4" deviation from the 10 ft straight edge or camber boards. Low places which develop shall be lightly raked and built up with further aggregate and binder from the stockpile.

The mix-in-place course shall be allowed to set up to the approval of the Engineer (usually more than 7 days) before the next coat.

Emulsion Penetration (see MHB 49)

The Engineer's approval must be obtained before emulsion penetration work starts. Approval will not be given to surfaces which are dirty, irregular, uneven in texture or have other unsatisfactory features.

Emulsion shall not be applied when the air temperature in the shade is less than 40°F. When the temperature is below 60°F the emulsion must be heated before application but it shall not be heated above 110°F. The heating arrangements of ordinary sprayers are sufficient for the small amount of heating required at any time.

Spraying shall be done with an approved hand or engine operated sprayer at a pressure of not less than 25 lbs per square inch nor more than 75 lbs per square inch. On small

jobs hand pouring from cans fitted with suitable baffles may be allowed. The emulsion must be distributed evenly.

The rate of application shall be approximately 1/3 of a gallon per square yard. This may have to be adjusted, depending on the density of the mix-in-place work. There shall not be an excess of emulsion to flush the surface.

Before the emulsion loses its chocolate colour 1/4" grit shall be uniformly spread over the surface at the rate of 1 cubic yard to 150 to 200 square yards. The grit may be evened out by careful brooming. Rolling shall immediately commence with a roller weighing not less than 4 cwt.

All equipment used for spraying emulsion must be kept in a clean condition. Immediately on the stoppage of spraying, pumps, pipes, spraybars and nozzles must be flushed with oil or kerosene and oil. Care must be exercised to ensure cleanliness if the machine is to continue spraying efficiently and satisfactorily without spluttering and stoppage.

The limits of surface accuracy used previously shall apply.

Seal Coat

The seal coat may be applied within the following few days or weeks.

The previous coat shall be drag broomed to an even texture and distribution of surplus grit. Deficiencies may be made up by adding grit. Surface irregularities may be evened out at this stage. The surface shall then be rolled. The surface shall be clean.

Quick breaking emulsion shall then be applied using similar plant to that for the penetration course and under the same operating conditions. The rate of application shall be between 1/5 and 1/6 of a gallon per square yard.

Sand shall then be uniformly spread, and drag broomed and rolled before the emulsion breaks. The approximate rate of coverage is 150 to 200 square yards per cubic yard of sand. Rolling shall be continued until the surface is flat and tight. Additions of sand shall be made to ensure an even texture. The finished work should comply with the accuracy limits of 1/4 inch variations from a 10 ft straight edge, have no water holding hollows and no visible irregularities in surface slope or texture.

METHOD 3

This method consists of a light tar primer coat followed by a tar or bituminous macadam coat 3/4 of an inch in depth. The specification for this coat is set out below. The final

surface finish is the same as that for Method 2 Seal Coat.

Prime Coat

Light tar primer shall be applied at the rate of 1/5 of a gallon per square yard in accordance with the detailed specification in Method 2 Prime Coat.

Tar Macadam Coat

Tar macadam is produced by mixing 3/8 inch down mineral aggregate and light sealing tar. This can be done in a concrete mixer if desired. The approximate proportions shall be 5% of tar to 95% of aggregate by weight. A trial run will indicate the exact quantities required. All particles of the aggregate must be covered, and there should be no surplus free flowing tar.

The macadam will be spread to a loose depth of 3/4" with rakes or board screeds, and rolled with a roller weighing more than 4 ton. Additions of macadam shall be made to bring the surface to the required degree of 1/4 inch accuracy.

Seal Coat

A quick breaking emulsion and sand seal at the rate of 1/6 of a gallon of emulsion to a square yard and to the same general specifications as Method 2 Seal Coat should then be applied.

METHOD 4

Method 4 is composed of a light tar primer coat followed by an emulsion penetration course which is specified below. The final surface finish is the same as for Method 2 Seal Coat.

Prime Coat

Light tar primer shall be applied at the rate of 1/5 of a gallon per square yard in accordance with the detailed specification in Method 2, Prime Coat.

Emulsion Penetration Course

When the prime coat has set up a light tack coat of emulsion at the rate of approximately 1/6 of a gallon per square yard shall be applied. Before this breaks Grade C chips shall be spread to a depth of 3/4 of an inch. The chips must be evenly spread and dressed to a flat surface with hand or drag brooming. Rolling shall commence immediately the chips have been applied. The roller should weigh more than 4 tons although in confined places hand rolling may be permitted.

A delay in excess of three hours or even a few days must be allowed before the penetration course. The chip surface must be checked for cleanness and surface accuracy. The last process before penetrating with emulsion shall be rolling.

Quick breaking emulsion shall be applied in the manner set out in Method 2 Emulsion Penetration. The rate of application will depend on the depth of rolled chips as finished, and the amount of prime coat on the metal surface. The rate will be between 2/5 and 1/2 of a gallon per square yard.

Immediately following the emulsion application 1/4 inch grit shall be thinly spread over the surface in just sufficient quantity to prevent pickup by the roller. Additional grit shall be applied to even out texture or surface irregularities.

Rolling shall continue until no movement occurs. The final surface accuracy shall be as previously specified - namely less than 1/4 inch deviation from a 10 ft straight edge or camber board.

Seal Coat

A quick breaking emulsion and sand seal at the rate of 1/6 of a gallon of emulsion per square yard blinded with sand and to the same general specification as Method 2.

METHOD 5

This is plant-mix surfacing.

Plant Mix Coat

The bituminous material for plant mix work shall be $SC_{3/4}$. The mineral material shall be 1/4 inch down plant mix grading for coats less than 3/4 of an inch loose depth. The specifications for materials and grading of aggregates, and the method of manufacture are set out in Specification 48 (July 1946). Special plant is required for manufacturing plant mix and it should be obtained from the plants when required.

The primed metal course must be dry and clean before commencing laying of plant mix. Air temperature in the shade must exceed 55°F. A light tack coat of 1/6 of a gallon per square yard of emulsion should be applied. If the area being paved is sufficiently large so that heavy plant can be used, MHB 48 can be adopted as the specification. For small areas hand work will be required. Plant mix should be spread by barrow and shovel and raked into position. Rolling shall commence immediately with a roller weighing in excess of 4 tons. A continuous check of surface smoothness shall be made to the same 1/4 inch accuracy as previously set out. Special care is necessary with this type of work as irregularities are more noticeable.

Plant mix shall not be dumped onto adjacent pavement. If it cannot be dumped in place, it shall be tipped onto steel plates or timber platforms or distributed directly from the delivery truck.

Seal Coat

If desired a seal coat of quick breaking emulsion and sand to the general specification of Method 2, Seal Coat, may be applied to the above surface.

METHOD 6

This method may be applied after any of the above coating methods where a specially fine surface is desired. It is most useful for finishing tennis courts, when two coats shall be applied, the first across the court and the second parallel to the longer axis. Two coat work shall always be laid so that the coats are at right angles.

The surface shall be thoroughly cleaned by brooming or even washing. All loose material shall be removed. The surface shall be tested to an accuracy of 1/8 inch deviation from a 10 ft straight edge. Low places shall be built up by a light tack coat of quick breaking emulsion allowed to set, and followed by floating on a mixture of sand and undiluted squeegee emulsion. This mix sets quickly.

Slow breaking emulsion to the standard previously defined shall be used. Sand as previously specified, or other fines if readily available, shall be used. It must be clean but may be damp.

Squeegees shall be sturdily constructed and preferably of the following type. The squeegee shall be formed like a broom having a blade of rubber 3 feet long, 6 inches wide and 3/8 of an inch thick, firmly held between two pieces of timber 3 ft long by 6 inches by 1/2 an inch or thicker, with the rubber projecting 1/4 of an inch for rough squeegee work, and 1 inch for fine finishing work. The edge must be straight. The corners should be rounded to prevent scratching and scouring.

When surface and tools are ready a squeegee mortar and wash shall be prepared.

The mortar shall consist of slow breaking emulsion and sand. Portland cement may be added to assist setting up or in poor weather. The cement should be at the rate of 2½% by volume of sand for preference, certainly not more than 4%. The sand and cement are mixed thoroughly first. Four parts of

sand or sand and cement by volume are mixed with one part of squeegee emulsion. The exact proportions depend on the sand grading so care must be exercised to obtain a mix in which all particles are just covered. Mixing may be done on a board or in a mixer. A small quantity of water may be added if the sand is very dry.

The wash shall consist of 2 parts by volume of clean water and one of squeegee emulsion. In hot weather the water volume may be increased to 3 parts. Mixing should be thoroughly performed in a drum.

Laying may then proceed. The wash shall be poured on and squeegeed into the surface with a rough squeegee to fill all the voids. Mortar shall be quickly spread behind the wash, broomed, slurried and finally squeegeed into place. Squeegees shall operate in pairs on the final surface. The leading rough squeegee shall remove the surplus material and the fine finish squeegee shall follow to produce the final surface. Squeegee operators shall work to the side of the completed work. Squeegee runs shall overlap slightly so that no ridge is left.

In hot weather this work sets up quickly and it is therefore better to do it when drying conditions are not too severe.

The second coat is applied in exactly the same manner but at right angles to the first. The final surface accuracy should again be checked and any deficiencies made good.

Departmental Specifications and Instructions relating to and incorporated in the above paper are listed for reference:

B3	1954	Crushed Stone Top Course Construction.
F1	1956	Construction of Formation.
M1	1954	Asphaltic Bitumens
M2	1954	Tar Primers and Sealing Tars.
M4	1958	Crushed Base Course Aggregate.
M6	1958	Sealing Chips.
P1	1954	Tar Priming Coat.
P2	1958	First Coat Sealing, Binder,Medium Sealing Tar.
P3	1954	Dust Laying Seal Coats, Binder, Asphaltic Road Oil Cutback.
48	1946	Plant Mix Asphaltic Surfacing (Specn).
48A	1946	Plant Mix Surfacing (Notes)
49	1946	Emulsified Asphalt Surface Treatment (Specn).
49A	1946	Emulsified Asphalt Surface Treatment (Notes).
51	1946	Mix in Place with Emulsion Sand Finish.

Commercial literature is also available.

The writer is indebted to H.J.L. Wotten, District Highways Engineer, Wellington, for assistance in compiling the specifications contained in this Paper.

COMMENT

By F. M. Hanson

Mr Lovatt rightly calls attention to the fact that ordinary chipped road sealing is not a suitable surface for pedestrians. Footways should have a smooth surface free of loose or protruding chips.

There are many combinations and variations of light bituminous treatments which will provide a smooth durable surface for pedestrian use and which can be laid in confined and restricted areas. Also, it is possible to design a footpath surfacing which can be put down in almost any reasonably dry and non-frosty part of the year.

Many non-plastic local aggregates are quite suitable as a base for the bituminous surfacing. River shingle, rotten rock of various non-plastic types, scoria and other local materials make a good foundation for pedestrian paths and will also carry light vehicles.

One of the simplest classes of surfacing for footpaths or motor car drive-ways is -

(1) Start with a layer of rotten rock or corresponding local material.

(2) Cover with 3/4" chips to a loose depth of about 3/4" to 1" and penetrate with emulsion.

(3) Blind the surface with a sprinkling of fine plant mix.

This type of surfacing can be done over a large area using the usual roading plant or in smaller areas the work can be done entirely by hand with the simplest of equipment. Emulsion can be applied expeditiously and economically by hand pouring on even quite large areas.

The local non-plastic aggregate of whatever nature should be rolled or compacted as circumstances will permit after the subgrade has been treated with a weed-killer wherever this may be necessary. Very little or no water should be used so that the aggregate will usually not be bonded together, but it should be pressed down reasonably hard and tight. On this surface is spread the 3/4" to 1" of clean and preferably washed 3/4" chips (a wider grading will be quite

acceptable). Good workmanship and true spreading at all stages will pay dividends in providing a smooth finish.

The 3/4" chips are raked and rolled to a smooth surface. Hand rolling will serve quite satisfactorily. Without disturbing the surface, emulsion penetration is carried out using about three-quarters of a gallon per square yard. It must be stressed that the chips should be clean and if it is hot and sunny weather it will be advantageous to lightly sprinkle the chips with water just prior to the application of emulsion.

Following the emulsion penetration plant mix ($SC_{3/4}$) all passing 1/4" is sprinkled over the surface before the emulsion turns completely black. Plant mix will have been stockpiled at the job. The plant mix must not be dropped or dumped in heaps but it should be carefully sprinkled from a shovel so that there is only just enough to fill the voids or interstices in the penetrated chips. Very careful brooming may be employed to assist in achieving a light uniform spread of plant mix. One ton of plant mix should fill the interstices in at least 50 square yards of surface.

The plant mix is rolled with an orthodox roller, following which a motor car or light van can be run over the surface to effect further compaction. If any hollows show up the surface should be raked and a little more plant mix added and rolled.

It will be noted that there is only one application of bituminous emulsion and no prime coat is required in this class of surfacing. The plant mix required is comparatively small in quantity and therefore can be railed or hauled for some distance without unduly increasing the overall cost of the job.

The bituminous surfacing itself, in the case of pedestrian areas, will generally cost more than the bituminous sealing of roads, but the preparation and metalling of pedestrian areas will cost much less than road preparation. The work of preparation and paving of school grounds, footpaths, etc. in some aspects calls for a much wider knowledge of bituminous treatments than does roading. For this reason some engineers are inclined to avoid these playground paving tasks, but rather than avoid them they should seek them, because no other class of bituminous paving provides so much understanding of the fundamentals of bitumen sealing and paving as does playground work and paving of footways.

THE CAUSE AND TREATMENT OF SLICK SURFACES ON SEALED PAVEMENTS

By D. J. B. Halley

The object of surface sealing as practised in New Zealand is to provide a low-cost dust-free smooth-riding waterproof surface which is non-skid and non-reflective.

A dust-free surface is probably the most desirable property from the road users' point of view, and a truly waterproof surface the most difficult to attain. The degree to which the other properties are achieved is entirely in the hands of the Engineer and depends on the knowledge and application of the fundamental principles of sealing laid down many years ago.

Failure to apply these principles too often results in built-in hazards, featured in accident statistics as "road faults" the most common one being a slippery surface.

Slippery surfaces on a pavement result from various causes. Many properly constructed pavements become slippery after years of use when the chips have worn down to the level of the binder, producing a flat glassy mosaic of stone and binder. This is a condition which usually calls for a normal re-seal. Another type of slippery surface far too frequently seen on our highways is what is called a "slick" surface, where the bituminous binder has been forced up through the chips or aggregate, completely filling the voids, and has flowed over the surface of the pavement to a greater or lesser depth.

It is the intention of these notes to point out the most common cause of this condition and to suggest various treatments when it occurs.

A slick surface results from an excess quantity of bitumen being used at some stage in the build-up of the bituminous surfacing. Without doubt the most common causes, more particularly with seal coats, are rule of thumb methods of determining the amount of binder to be applied to the road, and careless control of its application.

Methods of determining the amount of bituminous binder to be used in sealing work are described in Mr Hanson's paper on "Bituminous Surface Treatment of Rural Highways" in the 1934/35 Proceedings of the N.Z. Society of Civil Engineers, and experience gained since then, while it has brought modifications to some of the techniques he advocated, has more than amply borne out the correctness of the fundamental principles he enunciated.

These may be summarised as follows:-

(1) A knowledge of the average least dimension of the chips to be used to form a cover coat is an essential prerequisite for the correct determination of the rate of application of binder.

(2) The average least dimension of the chips forming a cover coat aggregate is approximately equal to the average compacted depth of the cover coat, that is, the depth of the coat after rolling and compaction under traffic.

(3) The minimum loose depth of chips to be applied is obtained by multiplying the A.L.D. of the chips by 1.6, that is to say the coverage in square yards per cubic yard of chips is obtained by dividing 36 by 1.6 times the A.L.D.

(4) The voids in the chips laid loose is approximately 50% reduced to 30% after compaction by rolling which again is reduced to 20% after further compaction and abrasion under traffic.

(5) Where the bitumen is less than 20% of the compacted volume of the chips a mosaic non skid surface is obtained; where it exceeds 20%, a slick surface is the result.

(6) The recommended safe amount of binder to produce a protruding chip and a non-skid, non-glare surface is 70% of the final compacted void space, that is 14% of the compacted volume of the chip aggregate. (For example, with 7/8" - 5/8" chips having an A.L.D. of 0.45, the maximum safe depth of binder is 20% of 0.45" = 0.09" and the recommended depth is 70% of 0.09" = 0.063", which is equivalent to 0.31 gallons per square yard. It is interesting to note that this is the recommended spraying rate for an A.L.D. of 0.45" in a table given in Specifications P4 and P5, dated 1954).

It may be said with some justification that this is all elementary as indeed it is. But it is the neglect of these principles, or the delegation of their application to those who don't understand them which is the chief cause of the failures which occur and in particular, the failure which results in a slick surface. It is for these reasons they bear restating.

Careless spraying is also a prime cause of slick surfaces. However correctly the spraying rate is calculated, it is of little avail if close control is not kept over the actual operation of the sprayer. In this respect it is essential for the sprayer to be accurately calibrated by

the Engineer - this is no job to be delegated - so that quantities of binder delivered to the road can be quickly and accurately checked at frequent intervals.

Slick surfaces generally fall into one or other of the following types:

(1) Small localised areas where the excess bitumen is the result of a local alteration in the spraying rate, caused by starting and stopping the sprayer, overlapping, or where small smooth impervious surfaces are encountered on an otherwise rough-textured road surface.

(2) Longitudinal shoulder slicks resulting from the lighter bitumens flowing across the road due to excessive camber and perhaps very hot weather.

(3) Longitudinal slicks due to differential compaction along wheel tracks where one lane carries heavy dense traffic.

(4) Slick surfaces covering the whole or most of the pavement on surface sealed roads.

(5) Slick surfaces covering the whole or most of the pavement on bituminous concrete or plant mix surfacing.

(6) Slick surfaces covering the whole or most of bituminous macadam pavements (penetration).

In deciding on the treatment to be given to all these types of slick surfaces, the first thing to ascertain is the depth of the slick above the average level of the chips or aggregate as it is this factor which more than any other determines what treatment shall be applied.

A film 1/50" thick is equivalent to roughly 1/10 gallon per sq. yard. Films exceeding this can be termed thick and below it thin.

Small localised slicks are seldom serious enough to warrant special attention except when they occur at regular stopping places where they tend to produce marked corrugations. In these cases the slick can quite often be scraped off down to the chip surface with a grader, or it can be burnt off to expose the chips with a portable burner. Burning is a slow and costly process and is not recommended for the treatment of large areas. If the slick is not corrugated and is appreciably thick, it can be sprayed with 1/15 to 1/10 gallon of kerosene per square yard to liven up the bitumen, after which the size of chip appropriate to the amount of free bitumen is applied and thoroughly rolled.

If the slick is thick, and being retreaded in the summer it is of course, often possible to pick a hot day when the slick is soft, to roll in chips without spraying with kerosene, but even here a better take will be obtained if the chips are coated with kerosene before being spread.

Where the slick film is very thin, and if it is reasonably certain the whole of the surplus bitumen has come to the surface various re-sealing treatments may be applied with safety, such as a light emulsion seal, an asphalt cut back to an MC_2 specification, with a suitable chip, all depending on the time of the year.

What must not under any circumstances be attempted - and this applies to the treatment of any slick surface - is to superimpose a seal coat with a normal rate of application of binder on top of a thick slick. This will only perpetuate the slick conditions.

Longitudinal slicks, either on shoulders or along wheel tracks are quite common. They seldom attain any great depth, in which case it is generally safest to leave them alone. Where the longitudinal slicks are appreciably thick and call for some treatment, the greatest care should be used in the use of any of the abovementioned measures, due to the risk of forming a longitudinal ridge which tends to prevent the runoff of surface water. If the thick slick cannot be burnt or scraped off, then the recommended treatment is to liven the slick with a light application of kerosene and cover with a 1/4" grit.

The really dangerous slicks are those which extend beyond the safe stopping distance of a motor vehicle and cover the whole or most of the traffic lane. These slicks are the result of a uniform over-application of bitumen; on a surface seal because of too high a spraying rate, and on a plant mix because of too high a proportion of binder, due generally to an inaccurate estimation of the void ratio in the mix after final compaction under traffic. Large slick surfaces on bituminous concrete or bituminous macadam are relatively unimportant as these types of pavement are not common. Where they do occur the slick is generally thin and the surfaces can usually be re-sealed with emulsion and a medium or small chip aggregate, due allowance being made for the surplus binder on the old surface.

The slick surface commonly observed which is responsible for most of the accidents resulting from slippery surface conditions, is that which covers substantial areas of surface

sealed pavements. These slicks sometimes extend over distances of many chains, and the slick is often quite thick over the whole length. When one's attention is forcibly drawn to a section of road in this condition by an accident, traceable to the slippery surface in cold or wet weather, one's first reaction is to rip up the surface and put down a fresh dust-lay seal, rather than employ some other cheaper treatment, with the risk of aggravating the position. This is a natural reaction for Engineers inexperienced in these techniques, but considerations of economy alone should encourage engineers to draw on the experience of others. This experience has proved the following treatments to be quite successful:

1. Where the slick surface is composed of a very thin film of bitumen say less than 1/50" thick and compaction of the surface aggregate is complete, then a full application of new binder may be safely made, using an asphaltic road oil or an MC_2 or even an emulsion, provided all are correctly proportioned to suit the A.L.D. of the chip cover coat.

2. Where the surplus bitumen forming the slick exceeds 1/50" in thickness and is thick enough to hold a chip without the addition of further binder, a satisfactory non-skid cover coat has been achieved by spraying the slick surface with kerosene at the rate of from 1/10 to 1/15 gallon per sq.yard, covering with chips 1/4" to 3/4" thoroughly rolled in.

3. Given warm weather, thick slick surfaces have been successfully retreaded by rolling in chips without any application of kerosene, but the chance of success with this simple method is enhanced if the chips are first coated with kerosene.

4. Another method, which has been suggested by Mr Hanson, is to lightly spray the slick surface with emulsion, rolling in a large chip, say 7/8" - 5/8" and then spraying emulsion on to the chips at the rate of about 1/10 gallon per sq. yard, following up by rooming a 1/4" grit into the interstices of the chips, and further rolling.

   The first application should only be heavy enough to enable the heavy chip to adhere to the old surface, the second application bringing the total amount of binder to the correct amount as determined by the A.L.D. of the chip, taking into account the surplus binder in the old surface into which the chips are pressed.

The 1/4" grit which is broomed in locks the chips tightly together and should produce a smooth riding silent non-skid surface.

COMMENT

By F. M. Hanson

As will be gathered from Mr Halley's paper a "slick" or a "fatty" bituminous road surface is not a simple problem and there is no one solution which has merit over all other treatments. A "fatty" surface is frequently built up with successive reseals more than with the initial seal. The best approach to a "fatty" surface is to prevent it. Proper care and precautions should be taken to ensure that any bituminous work on a road will not lead to "fatty" conditions.

"Overlay" as described in Mr Neale's paper is a method which has been used to overcome a "fatty" bituminous surface. "Overlay" treatment would be quite effective but the cost generally would be much too high. Scarifying, adding metal, recompacting and sealing, just as with "Overlay", would eliminate "fattiness" but again the cost would be too high.

Mr Halley has set out several methods of attacking a "fatty" surface. Under the right circumstances any one of the treatments which he describes will be effective, but I do issue a note of warning in regard to any kerosene treatment. Kerosene makes the surface very lively for from 24 to 48 hours. During this period there is a real danger of vehicles going into a serious skid if speeds are not kept right down. Therefore, do not use a kerosene treatment unless adequate precautions can be taken to ensure that speeds both by day and by night are kept to only 10 or 15 miles per hour. Kerosene treatment can be very successful but I cannot stress too strongly the danger which will be created if speeds cannot be controlled down to a low level.

In the case of a surface which has worn smooth rather than "fatty", Mr Halley suggests that an MC_2 or an emulsion seal might well be the treatment. If small chips, say 3/8" are available, I would prefer an emulsion seal, but if only larger chips are on hand then one of the MC products could be used. A smooth rather than a "fatty" surface frequently obtains with an old well-worn bituminous concrete, but any of the bituminous pavements under certain circumstances can reach the same smooth conditions.

Under sound engineering practice there should be no very "fatty" surfaces, but we have not yet reached this desirable stage for all too frequently very "fatty" or "slick" surfaces with attendant "bleeding" in hot weather, and slipperiness in winter months, are encountered in various parts of the country.

Method (4) as set out by Mr Halley describes my suggestion for the treatment of very "fatty" or heavily "flushed" bituminous surfacing. In this Method (4) treatment the initial application of emulsion should be only just sufficient to tack the large chips down, remembering that for a while the surplus bitumen causing the "fattiness" will not rise up to hold the chips. The amount of first emulsion application will not hold the chips sufficiently to withstand traffic action and therefore a further emulsion spray blinded with grit or coarse sand on the top of the large chips immediately following the rolling of the chips will prevent "scabbing" in the early stages. This will allow the surplus bitumen from the bottom to be "kneaded" up round the chips.

I believe that the top spray of emulsion at one-tenth of a gallon per square yard as set down in Mr Halley's paper, is too light from a practical point of view. I think that a reasonable coverage will not be achieved with less than about one-fifth of a gallon per square yard which will give deposited bitumen of one-tenth of a gallon per square yard. The initial application of emulsion must be adjusted accordingly. If the "flush" surface is not uniformly "fatty" the initial application of emulsion can be varied to meet surface conditions, providing that hand spraying is adopted.

I must emphasise that it is bad practice to leave a road surface in a "fatty" state and engineers have a responsibility to motorists to prevent or to eliminate these undesirable and sometimes dangerous conditions.

THE CONSTRUCTION OF METAL COURSES FOR SEALING

By J. G. Ball

Function of a Metal Course

A road is a load bearing structure and all the loads superimposed on it, together with the dead weight of the road itself must finally be transferred to and supported by the subgrade. For the road to remain stable, the stresses caused by wheel loads must be reduced to a value that can be safely supported by the subgrade and this is the primary purpose of the road foundation.

Road foundations are broadly grouped into two types - rigid and flexible; the former generally means concrete whilst the latter is normally some form of coarse metal bonded with fines.

This article is concerned only with the latter type.

Desiderata for Metal Courses

Any metal course which is to be sealed must be highly stable and have sufficient rigidity to transmit the wheel loads without deflection sufficient to cause cracking of the surface. It must not be affected by water, must be hard enough to resist the impact of traffic over many years and must be capable of taking the binder for sealing.

It is also very desirable that it should be reasonably cheap, capable of being laid to an accurate finish, have low frost susceptibility, capillarity and absorption.

Determination of Construction Depth

The necessary depth of construction is a function of the subgrade strength, traffic density and wheel loads. A soil survey and Californian Bearing Ratio tests in conjunction with vehicle counts and other relevant information will determine the foundation depth. The manner in which this may best be achieved is a matter of engineering judgment.

It may be possible to effect economy by providing a sub-base of cheaper material, or a high quality surfacing course such as rolled asphalt may be justified. The matter is worth very careful consideration as it is likely to have a substantial effect on the cost of the job and a nice decision is necessary to evaluate the various possibilities.

Hardness of Metal

It appears reasonable that the hardest metal which is economically available should be used for the uppermost layers and that standard specifications should be judiciously varied to

suit local conditions. There is no point in specifying a standard of hardness which cannot be met nor in accepting a sub-standard material when a better one is available. It is clear that any stone used must not degrade from handling, wetting, drying and in most areas from freezing and thawing.

A possibility for the future is the use of an aggregate upgrading machine being developed in the U.S.A. This grades stones for hardness by utilising their bouncing properties to give different trajectories.

Base Construction

The cut-off layer (if required) and sub-base having been laid and compacted, there are three methods by which the base may be laid. These are:

(a) Waterbound macadam.

(b) Dry Choked macadam - and -

(c) Graded base course aggregate or "wet mix".

The principles involved are somewhat different, but each is capable of producing a dense base suitable for sealing which in the words of John Macadam, an early highway engineer and originator of the use of crushed stone, "shall unite by its own angles so as to form a solid, hard surface." (1)

(a) Waterbound Macadam:

In this form of construction broken stone screened to a close range of sizes, is spread over the formation in an even layer, bladed to correct shape and rolled with a heavy smooth wheel roller, starting at the edges and working towards the centre until compaction is achieved. Blinding material in the form of crusher dust passing 3/8" screen, crushed limestone, sand or other naturally occurring non-plastic material is then fed into the surface to the extent of about 25% of the original volume of the stone and worked with brooms and the roller until no more can be absorbed. The filler should be dry at this stage to enable it to sift more easily into the interstices. The surface is next watered and this is continued together with further rolling and sweeping until a wave of excess grout is carried before the roller. The process is complete when a slight excess of grout has been worked up over the whole area.

When the surface has almost dried out, a maintenance course of 1/2" chips is spread over it to protect the surface until it is sealed and to assist in removing excess filler which may coat the stone. The chips must not be allowed to ridge or be displaced from the surface, but should be maintained

at a uniform coverage by dragging or light grading.

This form of construction can be used for courses up to four or five inches in thickness with a large stone but a compacted depth of about 2½" to 3" is the more usual practice, for which stone screened from 2½" to 1½" is suitable. It is important that the depth of the course should not be much greater than the average least dimension of the largest stones or final compaction will be difficult to achieve.

Excess water must not be used or it may penetrate to the subgrade and weaken it. Any desired thickness of metal may be built up in successive courses but care must always be taken to provide a mechanical bond with the preceding course by light scarifying.

(b) Dry Choked Macadam:

This process was originally developed to overcome the difficulties caused by segregation which occurred with crusher run stone. The method is to build up the course by spreading single sized broken stone using a grader or spreader box.

One or two passes are made with a smooth wheeled roller to give the metal sufficient stability for the lorries carrying fines to pass over it without disturbing the surface and dry fines graded from 1/4" to dust are then spread evenly over the surface using lorries fitted with gritting attachments. Rolling is continued with the addition of fines until the voids are completely filled and the layer is fully compacted. A vibrating roller or vibrating plate compactor is ideal for this work and will achieve maximum density more rapidly than a smooth wheel roller.

This method differs from the waterbound technique in that the fines are induced to penetrate and fill the voids in the partially consolidated layer of stone and this reduces the effort needed for compaction. It also permits a greater ratio of depth to aggregate size and a 4" consolidated layer formed with 1½" stone has been found satisfactory. (4) It is essential in this method that the blinding material remains dry, otherwise full penetration is difficult to achieve.

(c) Graded Base Course or "Wet Mix":

The maximum stability in a metal course is only obtained when maximum density has been reached. To achieve maximum density, the grading must approximate closely to a certain curve for any specified size of material and this curve has been expressed in mathematical form by several investigators. Suitable gradings for base course are specified in Specification B/2 for 2½" and 1½" maximum size stone. If

the metal departs very much from a maximum density grading, consolidation cannot be achieved until the grading has been corrected by the action of rolling. AT THIS POINT, CONSOLIDATION TAKES PLACE RAPIDLY AND EASILY.

Dry base course metal having the tremendous range of sizes necessary for a good grading, tends to segregate badly when bladed or transported in lorries. The addition of a limited percentage of water helps to prevent segregation and also aids compaction by its lubricating action between the particles. The grading of crusher-run stone is rarely satisfactory for base course as it stands and some adjustment is usually necessary. Ideally the material should be screened into two or more sizes and recombined in suitable proportions, but an acceptable mix can often be obtained by adding a percentage of fines. Added fines may be crusher dust, ground limestone, or natural non-plastic sand or silts. In this connection it is worth noting that no separate payment is made for added fines and occasionally a contractor is disagreeably surprised when this is pointed out to him.

The mixing, wetting and spreading of the base course is traditionally carried out on the road with a power grader. This method worked well enough with plastic binders but with a modern non-plastic mix segregation becomes a difficulty. The present tendency is towards mixing the base course, either with a grader on a prepared site or using some form of pug mill and adding the optimum percentage of water as determined by compaction tests. The metal is then laid on the carefully shaped subgrade or sub-base with either a self propelled or towed type of spreader box and rolled with a heavy smooth wheel roller until full compaction is attained. Light watering is necessary to maintain optimum moisture content. A common practice in the U.S.A. is to add calcium chloride to retain the moisture and it is claimed that this helps to prevent frost action by lowering the freezing point of water, which may be present under the seal.

Towards the end of the rolling, the surface should be choked with 3/8" to dust crusher run metal produced from hard stone, to provide a dense, tight surface.

The maximum size of stone to be used in relation to the depth of course is set out in Specification B/2. For courses over 3" a 2½" stone is used and for courses of 3" or less, a 1½" stone. As a general guide, the loose depth of metal should be not less than twice the screen dimension of the largest stone.

Assessing Compaction

It is essential that full compaction be obtained before the road is sealed. Any movement after sealing will impair the riding qualities and result in cracking of the seal coat, with consequent ingress of water and attendant troubles.

Recent investigations in Australia (2) have shown that the usual method of expressing density as a percentage of the standard A.A.S.H.O. compaction is unreliable with crushed rock because of the variations in grading of samples from the stockpile. The alternative suggested is to express the density as a percent "solidity", viz. as a percent of solid stone present by volume. This is easily determined by field tests and it is claimed that a density satisfactory for sealing is 83% solidity. Whilst density tests provide a positive numerical indication of compaction, a good assessment of readiness for sealing can be made from surface indications by an experienced observer. A fully compacted metal course will show now the slightest amount of movement under a roller and the surface will be a closely-knit mosaic of stone and binder; there will be no signs of cracking or crazing and a peg bar or similar instrument struck upon the surface will emit a clear ringing note - not a dull thump.

Clay and Silt : Plasticity = Instability

The most important attribute of a metal course is stability and it follows that the individual constituents of any metal course must themselves be stable. Clearly any stone which is soft enough to break down by attrition or weathering or is chemically unstable must be avoided, but the dangers of unsuitable binders are less obvious.

It is a matter of common observation that the strength of clay is greatly reduced by the absorption of water and it is easily demonstrable that it has a considerable moisture movement, expanding when wet and shrinking when dry. These characteristics render it quite unsuitable for including in any metal course which is to be sealed and it is not an exaggeration to say the PLASTICITY IS SYNONYMOUS WITH INSTABILITY; the greater the plasticity, the greater the instability.

Deliberate inclusion of clay in the binder is not the only source of contamination. It is possible for clay to work up through the metal course if a cut-off layer has not been laid and especially if assisted by over watering. Lumps of clay from batters or water tables or the wheels of passing lorries can become pressed into the surface and will almost

inevitably reveal their presence by local failure at a later date.

Thin layers of clay may be present in an otherwise non-plastic metal pit and for this reason it is advisable to excavate in such a manner as to well mix the layers of stratified material. This also underlines the need for thorough sampling.

Silts, being non-plastic and of considerably larger particle size are less dangerous but they must be employed with discretion. A small percentage of silt may be used to increase the minus 200 fines, but it has been shown that quantities in excess of about 10% can result in bad failures. Silts also increase the capillarity of a metal course and render it more susceptible to frost damage by holding excessive amounts of water.

Ingress of Water

Water in combination with other conditions, is the chief factor in perhaps nine out of ten road failures. It is a good servant but a poor master.

It may be thought that if a sub-grade can be kept dry by good water tables and the seal well maintained, then no water can enter the road foundation to cause trouble. Unfortunately, this is rarely the case in practice, though attention to these points is of first importance.

Static water tests at Featherston and careful observation of the progressive deterioration and formation of potholes at Ngauranga and Plimmerton (3) have shown that water can penetrate a seal under the action of tyres and where clay is present, build up in the foundation to a point where it causes failure. This effect is magnified when water lies on the surface, so that adequate camber and shoulders flush with the seal will minimise this danger by shedding the water quickly.

Ground water is generally present at no great depth and this can rise by capillary attraction into the foundation. Condensation on the underside of the seal on cold nights can cause a concentration of water in this region with the possibility of frost damage. An open-graded cut-off layer and attention to the minus 200 fines content of the metal course will assist in preventing this.

Traffic Compaction

Consideration for the road user must always be a first duty of the highway engineer, even though this be not always

reciprocated and to give the travelling public the minimum of inconvenience should be a cherished ideal.

Traffic should not be expected to compact inches of loose metal, but as it is generally necessary for traffic to pass over the metal surface during the course of compaction, they should at least be guided into the channels where they will do least harm and most good. This can be achieved by careful drumming to distribute the traffic over the whole surface and this can be a very valuable addition to compaction. With moderately heavy traffic density, the effect will far outweigh the compaction from a steel wheel or pneumatic tyred roller and the lack of this assistance is very noticeable on works where traffic is sparse.

It is advisable to restrict traffic speeds to about 25 m.p.h. to avoid disturbing the surface by excessive forces and to limit the suction effect of tyres. This in itself is not an easy thing to do, but eye-catching notices, courteous requests and plain threats all have their place. Some modest publicity in the local press can be useful and the Engineer's arm is strengthened by the legal powers to impose temporary speed limits conferred by Section 31 of the Traffic Regulations 1956. It is most important that this power is not abused.

Preparation for Sealing

The preparation of the surface is the final operation on the metal course before the application of the tar or bituminous binder.

The surface should now be tight, hard and smooth, correctly cambered and without local depressions; it should show a high proportion of interlocked stone with only gritty material in the interstices. Any excess of binder remaining caked on the surface can usually be removed by drumming traffic onto it; otherwise it must be scraped off. The surface is them broomed to remove all loose material and if the binder is to be tar, a light sprinkling of water to just dampen it will help the tar to "bite". If a bituminous cutback is to be used the surface must be very clean and dry.

A non-plastic base course will not withstand the action of traffic for long without ravelling and it is therefore necessary to phase the work so that sealing can be undertaken within a few days of completion.

REFERENCES:

(1) Report of the Select Committee on the Highways of the King, 1819.

(2) Results of Road Research in Victoria. Commonwealth Engineer, December 1st 1955.

(3) Report on Roading in Tasmania. Hanson. Appendix II.

(4) The use of Different types of Crushed Rock and Industrial By-Products in Flexible Road Bases, by Armstrong and Sparkes, Road Research Laboratory, D.S.I.R.

COMMENT

By F. M. Hanson

Attention is called to earlier comment regarding the use of sub-base and the overall depth of sub-base plus metal and bituminous surfacing. Also it is again emphasised that there is danger from over-watering during compaction of Graded Base Course and "Wet Mix" when the subgrade is of any type of clayey material.

During the construction of Waterbound Macadam and Dry Choked Macadam there will not be the same strong tendency for compaction water or even early rain to penetrate or soak through the metal course. This is because of the initial compaction and choking before any water is applied. In the case of "Wet Mix" it is more difficult to prevent water from being squeezed into the subgrade.

Mr Ball does not seem to mention it, but I believe light sprinkling will assist final compaction of the Dry Choked Macadam. As a matter of fact there is very little practical difference between Waterbound Macadam and Dry Choked Macadam except that more modern equipment is used for the construction of the Dry Choked Macadam.

The grader is not the best means for spreading one size fairly large stone (perhaps 2" fragments) for Waterbound Macadam. For proper grader spreading aggregate must be windrowed and it is spread in cuts across the road, but large Waterbound Macadam aggregate does not respond very satisfactorily to such treatment. This class of aggregate preferably should be spread by means of a spreader box or better still, by a specially fitted up self-propelled spreader such as a Barber Green paver, equipped with the special metal spread-

ing attachments. Only when neither a spreader box nor a self-propelled metal spreader are available should the grader be introduced on this work. None but skilful operators will help much with a grader.

Under carefully controlled operations the methods set out by Mr Ball will provide very satisfactory sealing surfaces but perhaps in addition to Mr Ball's paper we should also have had a paper on the all too common mistakes and faults which occur in metal course construction. This is an aspect of roading on which there are so frequently no clear cut procedures. The methods adopted are often quite haphazard. It is not uncommon to encounter long lengths of uncompacted large aggregate left as a discomfort and even as a menace to traffic. Engineers should make every effort to eliminate these bad practices.

CHRISTCHURCH INTERNATIONAL AIRPORT

REPORT ON CONSTRUCTION OF RUNWAYS AND TAXIWAYS AT HAREWOOD AERODROME

By J. G. Sullivan

(1) GENERAL

Construction of the Christchurch International Airport Runways and Taxiways was commenced late in 1949 when Ministry of Works forces carried out preparatory work and began the construction of the runways.

By mid-1953 the layout was complete except for the taxiway approach to the South/West runway and this section of the work was put in hand early in 1958 and is now in the process of being sealed.

Throughout the construction Departmental forces have carried out the bulk of the work up to the underside of the topcourse while the placing of the topcourse and sealing have been done by a series of contracts, the Canterbury firm of British Pavements being the successful contractor in each case.

Runways were built to a width of 150 ft and taxiways to 75 ft.

A minimum overall depth of 3 ft 0 in. of metal was set as the required standard following laboratory tests for C.B.R. values, etc. and the fullest use was made of local materials, the Harewood area being an especially favourable one in this respect since it is situated on a riverbed deposit of reasonably well graded greywacke. It was necessary only to import sufficient fines to correct a deficiency of this material and Halswell loess which is non-plastic was used for this purpose throughout. Over the greater part of the area gravel extended to within a few inches of the surface. However, some portions were overlaid with silty material to varying depths, especially in the South/Western area.

(2) PIT-RUN FILLING

Over some 75% of the area to be sealed suitable gravel was already in place and wherever this state of affairs existed it was necessary only to strip topsoil and unsuitable material. Depth of excavation varied as required over the remainder of the area to a maximum of 3 ft 0 in. below finished surface level. An elevating grader feeding to approximately eight trucks was used for stripping.

Borrow pits for basecourse material were opened up at selected sites adjacent to the runways and taxiways. Stripping

both from the borrow pits themselves and from the areas under construction were dumped alongside and were later used to backfill the pits. This allowed a most economical sequence of construction since carry-alls could pay-load in both directions.

Filling was placed by carry-alls in layers and rolling was by construction equipment only. However, since heavy dozers - D-8's for the most part - and eight 10 ton Carry-alls were used throughout quite a good standard of compaction was obtained.

(3) STABILISED BASECOURSE

The pit run filling was covered by a further six inches (on runways) and nine inches (on taxiways) of the same material to which some 5% of Halswell loess was added. This was mixed by graders "ploughing-in" in a dry state. Watering, blading and rolling by grader followed. 8 to 10 ton iron-wheeled rollers were used for final compaction.

During the early stages of construction it was intended to remove all stone above 2½" diameter from the basecourse material and to construct to the highway standard then in vogue. However, it was soon apparent that the larger material could not be removed by raking as had been hoped and since any other method would have been expensive and since excellent results were being achieved with the material as it was the all-in material was used. Few stones exceeded six inches in diameter and approximately 5% only exceeded three inches.

The laying of this course completed the work carried out directly by Ministry of Works forces. (Note: Ministry of Works also constructed the bulk of the drainage system which item has not been included in this report).

(4) TOPCOURSE

The placing of topcourse to a consolidated depth of three inches was included in a series of topcourse and sealing contracts.

The first section done was a minor length of 800 ft of runway for which construction was required at an early date in order to tie-in with the existing runway requirements. For this area 3/4" maximum sized aggregate was used. It was specified that 50% of the surface area of all particles retained on the 10 mesh screen should be freshly broken. Compaction was by rubber-tyred vehicles with increasing loads. It is of interest that it was specified that transport vehicles and construction plant not equipped with pneumatic

tyres were not allowed on the topcourse during the final stages of construction or during the maintenance period.

The Contractor established a crushing plant alongside the Aerodrome for the production of the topcourse material and this set-up was also used for top-course metal for subsequent sections of the work.

For the remainder of the runways and for all the taxiways 1½" maximum sized aggregate was used and, apart from the recently completed South/West taxiway which is to the Christchurch Metal Course Specification; this was to M.H.B. No. 44 Topcourse Standards with amendments to cover the following:-

(i) 1½" maximum sized aggregate (circular screen) was specified; this was as for the M.H.B. 43 1½" Basecourse Specification.

(ii) The "approximate mixture" was varied accordingly.

(iii) 50% of the total surface area of all particles retained on the 10 mesh screen was required to be freshly broken.

In short the specification for the topcourse was to 1½" basecourse standard with 50% crushed surface area.

(5) PRIMING, SEALING AND PLACING OF PLANT-MIX SURFACING

(a) Primer:

Light tar primer was specified throughout, but over some areas an MC_1 cutback was used because of the non-availability of tar.

(b) Seal Coat:

Sealing for the earlier sections of the work was to M.H.B. No. 46 amended to provide for a 5/8" - 3/8" (circular mesh) chip. The South/West taxiway at present under construction is to Specification P4, amended to provide for a 5/8" - 3/8" (square mesh) chip.

Coverage throughout approximated 0.33 gals/sq.yd.

(c) Plant Mix:

The placing of Plant Mix was to M.H.B. (Provisional) July 1946. An application of four tons per 100 square yards was allowed for in the contract for the sealing of the runways, but the actual application rate was 2¾ tons. In the later contracts for the taxiways the application rate was reduced to two tons with the exception of the current contract for the South/West Taxiway which provides for 1.5 tons per 100 square yards and specifies that the minimum practical application is to be aimed at.

The tack coat throughout has been MC_3 at the rate of 0.1 gals/square yard.

(6) COMPLETION DATES OF VARIOUS AREAS

The several stages of construction followed each other closely on each section of the work. In fact in some cases contracts included the construction of topcourse, priming, sealing and Plant Mix application.

Approximate completion dates for the main area were as follows:-

Runways	31.3.51
N.W. and N.E. Taxiways	15.3.52
S.E. Taxiway	31.3.52
High Speed and Y Taxiways	31.5.53

The S.W. Taxiway now under construction was scheduled to be completed by 6.11.58 and should be completed as scheduled.

Negligible maintenance has been required as yet on any of the above areas. There has been some scruffing from wheels of turning aircraft and heavy wear from skidding of wheels during landing.

(7) COST OF CONSTRUCTION

Detailed costs are not readily available, but the costs of the current S.W. taxiway construction is indicative of the earlier work. They are as follows:-

Area involved:	33,700 sq.yds.
Cost per square yard up to top of basecourse:	12/2d. per sq.yd.
Rate per square yard for top-course, sealing and application of Plant Mix:	7/10d. " " "
Overall cost of construction:	20/0d. " " "

(8) IN SITU TESTS AND SAMPLES

During the month of October 1958 samples were taken from two areas on the Runways in order to get as-built information and to enable a satisfactory visual inspection of the seal to be made.

It was necessary to take these towards the end of the runways so as to interfere with air traffic as little as possible, but even so one of them was sited at a spot which gets very heavy landing patronage. It may be remarked in passing that it is surprising to the layman to note how near the end of the runway the bulk of the planes touch down.

Details of the test pits are as follows:-

(1) N.W. Runway Test Pit:

An area of seal approximately 15" x 15" was first removed. The effective depth of the "black top" was about an inch and it appeared "live" and in good condition.

A hole was then excavated to a depth of 2'8".

Three distinct layers were countered as follows and a sample was taken from each:-

(i) 0 - 4" A reasonably well graded partly crushed metal with a maximum diameter of 1½" and containing a sandy binder fraction. At 4" depth a definite layer of larger material was encountered. This had obviously been the surface of a well-compacted basecourse layer.

(ii) 4 - 9" Again a reasonably well graded metal, this time up to 3" diameter and containing very little crushed material and again containing a sandy binder fraction. At 9" depth a further change of material was plainly seen.

(iii) 9" - 2'8" Plain pit-run material to a maximum diameter of approximately 3".

A core approximately 8" in diameter and 6" deep was then trimmed out from alongside the test pit. This showed quite good grading of material and good compaction and the seal was firmly attached. All samples were immediately placed in plastic bags with the exception of the 15" x 15" area of seal.

The pit was backfilled to approximately 4" from the surface (in layers thoroughly rammed). Coated stone (tar) was then well rammed in thin layers to within 1/8" or so of the surface blinded off with Plant Mix, thoroughly rammed again to the level of the surrounding seal and then covered with emulsion and sand.

Great care was taken to sweep up all loose material before leaving the site because of possible damage to jet planes.

The position of the test-pit is shown on the accompanying drawing. Gradings are attached.

(ii) S.W. Runway Test Pit:

This proved to be almost a repetition of the first test-pit except that the basecourse was found at 3½" from the surface and the stabilised material extended down to 12½". Excavation was continued to depth of 2'9".

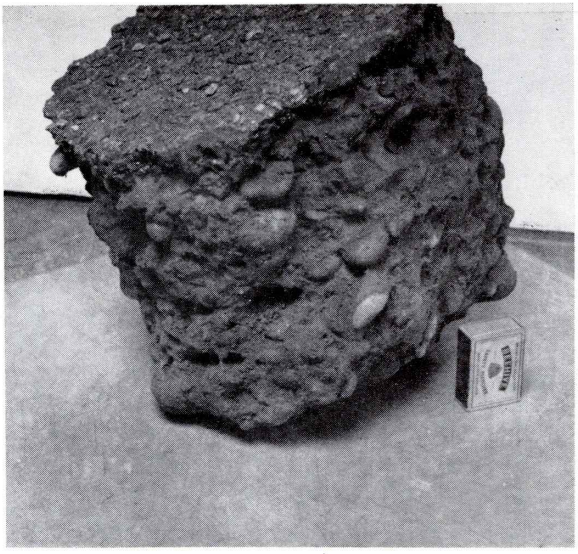
Samples were again taken and gradings are attached.

(9) FURTHER TESTING

It is noted that testing of the surface for L.C.N. values is to be carried out in the near future.

(10) CONDITION OF SURFACE

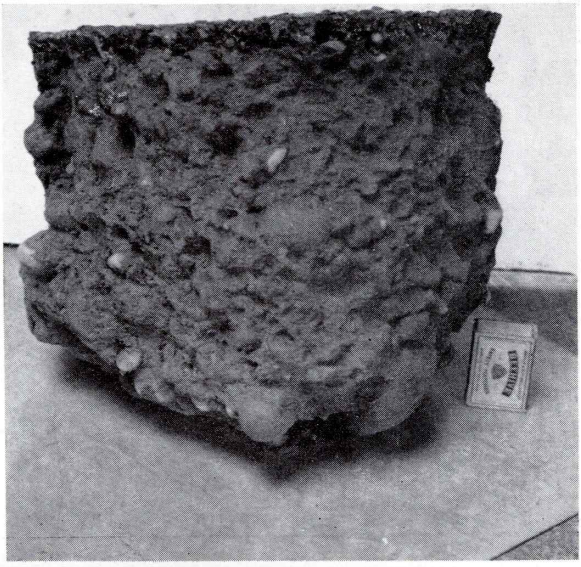
The general condition of the surface is excellent. However, some cracking is apparent over the surface on close inspection and although there is no tendency to spall at



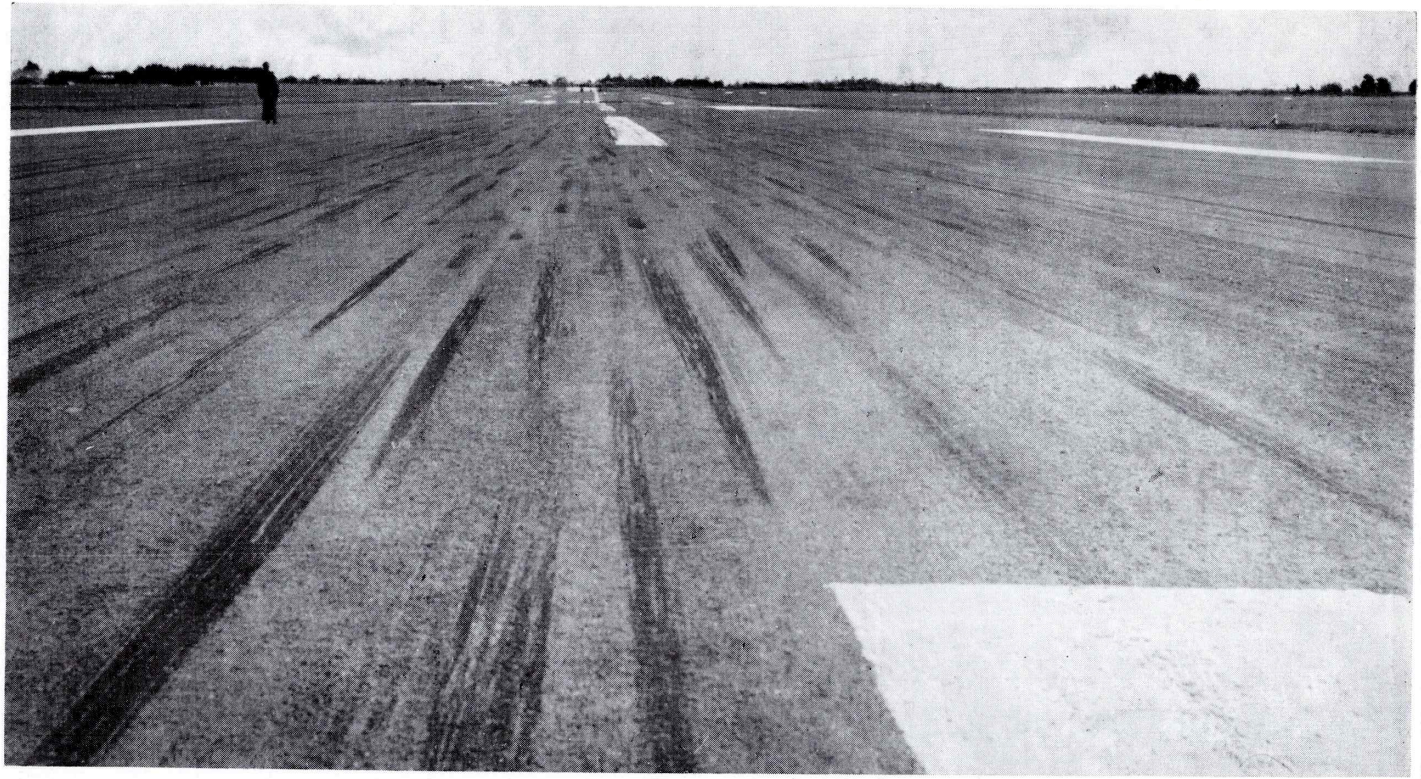
View of core taken from south-west runway test pit (15 October 1958)

Views of

CHRISTCHURCH INTERNATIONAL AIRPORT

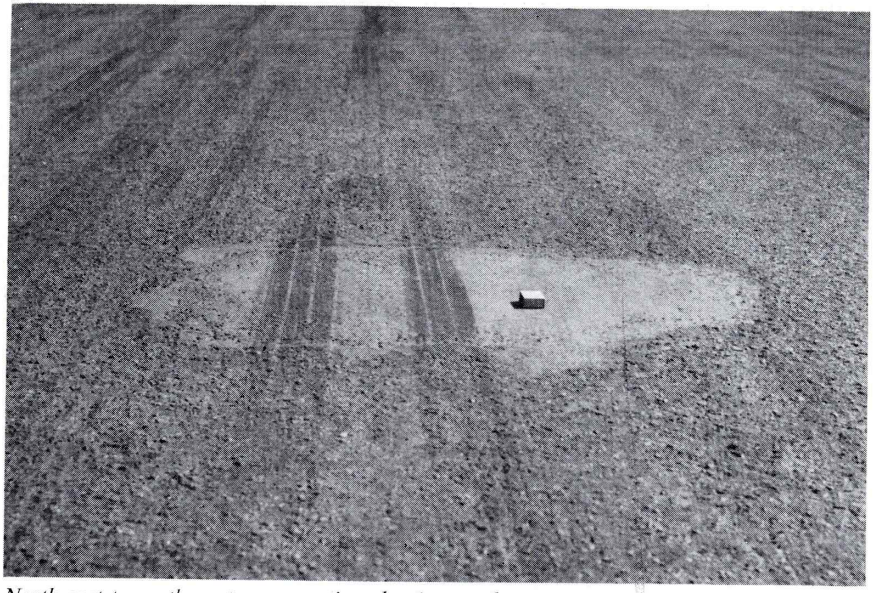


View of core taken from south-west runway test pit (15 October 1958)

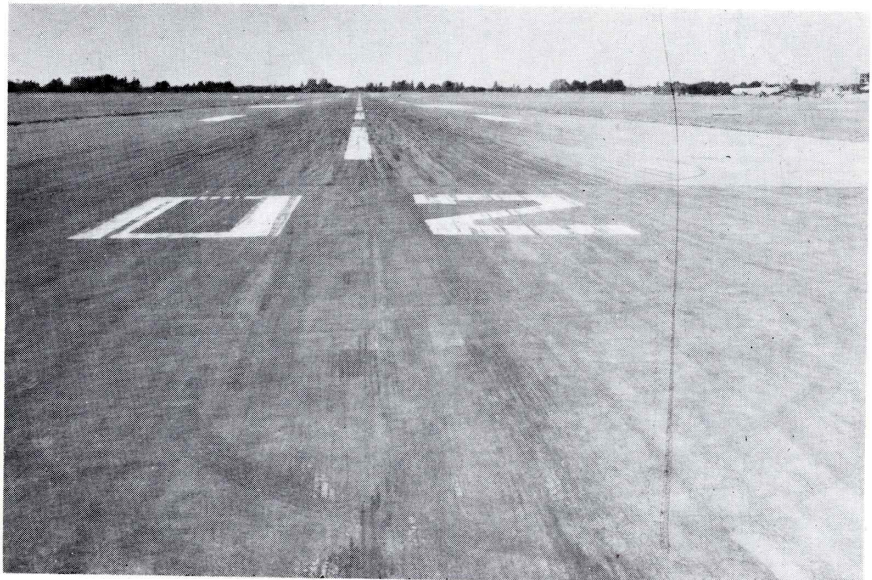


North-east to south-west runway: general view looking south-west (6 November 1958)

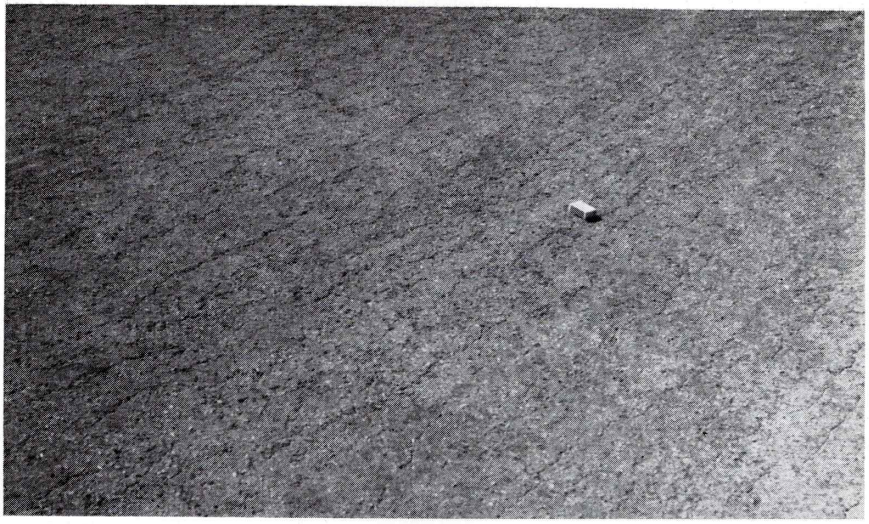
North-east to south-west runway: general view looking north-east (6 November 1958)



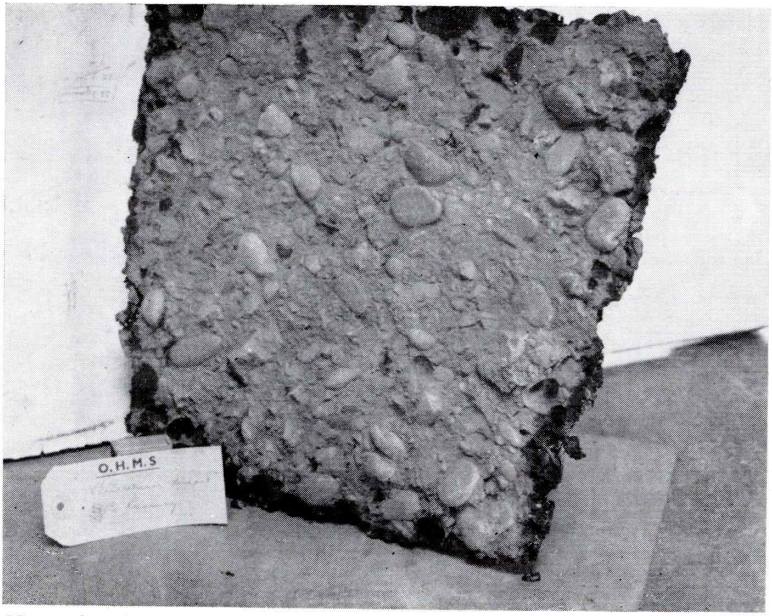
North-east to south-west runway: view showing patch over test-pit area (6 November 1958)



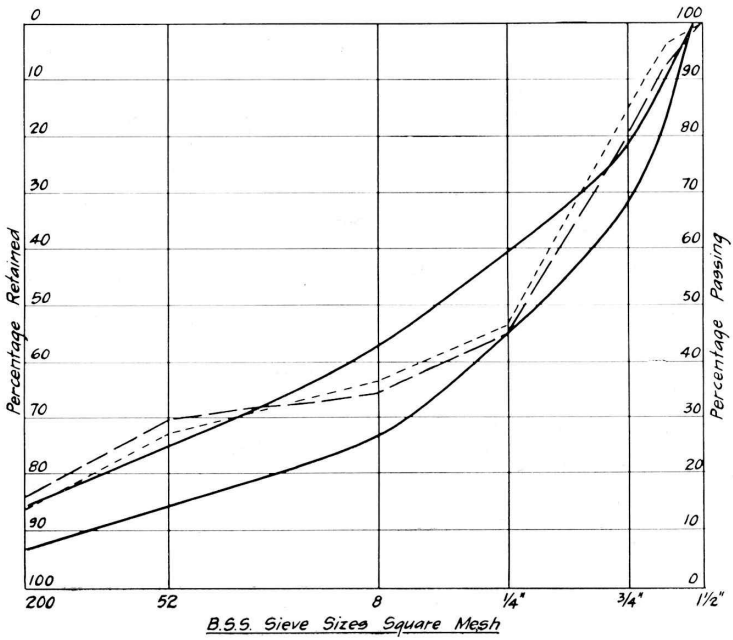
North-east to south-west runway: general view looking north-east from south-west threshold (6 November 1958)



North-east to south-west runway: view showing surface cracking on south-west sector (6 November 1958)



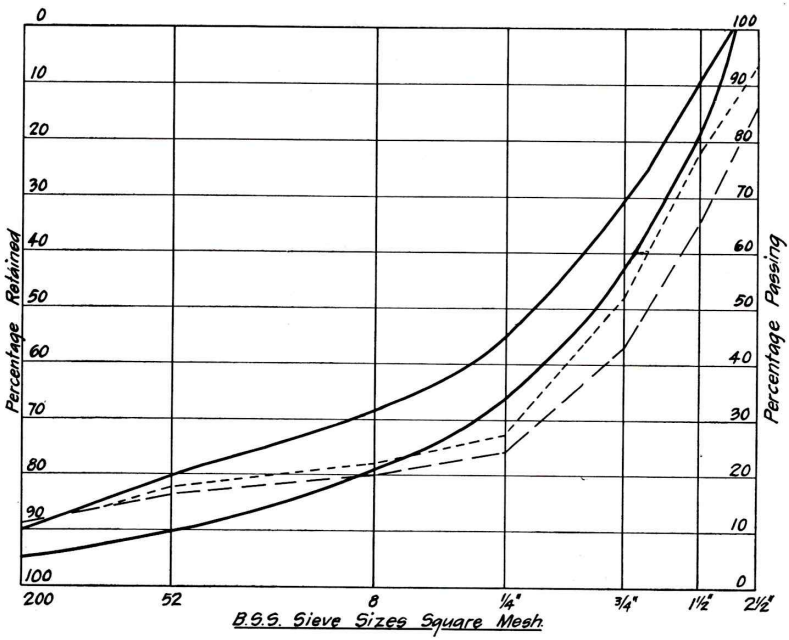
View of underside of sealed surface removed from north-west runway test pit (13 October 1958)



LEGEND : ——— Envelope of 1½" Basecourse from M.H.B. 43 on which Topcourse specification was based.
– – – – Grading of sample from test hole in N.W Runway at depth of 0" – 4"
— — Grading of sample from test hole in S.W Runway at depth of 0" – 3½"

	N.W. Runway Sample.	S.W Runway Sample.
Description	Greywacke, rounded and angular shape, waterworn and angular surface.	
Oversize	Nil	Nil
Broken Surface	50% approx.	40% approx.
Plasticity Index	N.P	N.P.
Moisture Content	3·6%	2·72%
Wear at 500 revs.	13·44%	

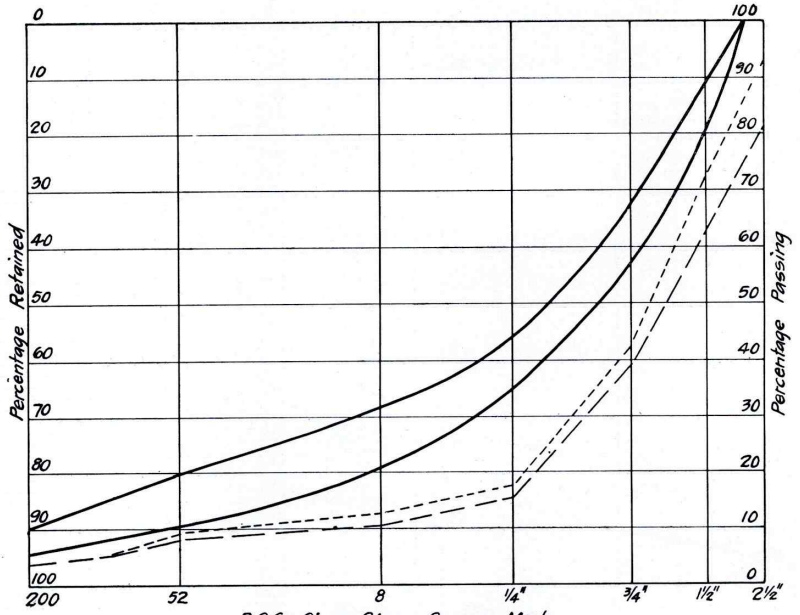
CHRISTCHURCH INTERNATIONAL AIRPORT
TOP COURSE GRADINGS FROM TEST PITS
OCTOBER 1958



LEGEND : ——— Envelope of 2½" Basecourse from M.H.B. 43 to which the stabilised Basecourse was expected to conform reasonably well.
----- Grading of sample from test hole in N.W. Runway, at depth of 4"-9"
— — Grading of sample from test hole in S.W. Runway, at depth of 3½"-12½".

	N.W. Runway Sample	S.W. Runway Sample
Description	Greywacke Rounded shape Waterworn surface	Greywacke Rounded shape Waterworn surface
Overeize	6·0%	13·9%
Wear at 500 revs.	13·44%	12·8%
Plasticity Index	N.P.	N.P
Moisture Content	2·02%	2·0%

CHRISTCHURCH INTERNATIONAL AIRPORT
STABILISED BASECOURSE GRADINGS FROM TEST PITS
OCTOBER 1958



LEGEND : ——— Envelope of 2½" Basecourse from M.H.B. 43 which gives comparative envelope for pit run filling.
----- Grading of sample from test hole in N.W Runway at depth of 9" – 2'-9"
— — Grading of sample from test hole in S.W. Runway at depth of 1'-0½" – 2'-9"

	N.W. Runway Sample	S.W. Runway Sample
Description	Greywacke - rounded and waterworn surface.	Greywacke - rounded and waterworn surface.
Oversize	6%	18%
Wear at 500 revs.	13·44%	12·8%
Plasticity Index	N.P.	N.P.
Moisture Content	1·34	1·1

CHRISTCHURCH INTERNATIONAL AIRPORT
PIT RUN FILLING GRADINGS FROM TEST PITS
OCTOBER 1958

this stage some treatment will be desirable over most of the area within the next year or so. It is likely that emulsion and coarse sand - say passing 1/8" mesh - would be sufficient to hold the surface for a further period of 2/3 years, following which a further seal and plant mix surfacing may be required.

Photos are attached.

(11) TESTING OF SAMPLES

Samples of the sealed surface have been forwarded to the D.S.I.R. Laboratory at Gracefield for analysis since suitable local facilities are not available.

Sieve analyses of the metal courses have been made and results are attached.

The two cores and samples of the "blacktop" are held at the Christchurch District Office Laboratory in St Asaph Street for inspection and for forwarding to Wellington as required. Photos are attached.

COMMENT

By F. M. Hanson

This paper will serve as a valuable record of the actual work on the runways of an important aerodrome. The very light type (less than 1") of bituminous surfacing used often amazes and even shocks engineers from some overseas countries where the practice is a two course bituminous carpet often providing not less than a total thickness of about 6". Experience already seems to have justified our work so that a true and faithful record of operations and materials will undoubtedly prove of great value for the future. Except for concrete ends the runway at Rongotai is similarly surfaced.

Some record of the aircraft using the aerodrome should be included and perhaps Mr Sullivan or some other officer at Christchurch will log this information. At this stage I can set out that the runways have been subjected to some quite heavy loading. The opening Air Pageant produced various types of aircraft including Canberras and other military jets. TEAL operates a regular trans-Tasman service with D.C.6 machines; NAC operates in and out of Harewood with D.C.3's and now Viscounts. Globemasters to service Antarctic expeditions were stationed at this aerodrome. These latter are very large aircraft but, of course, they do have large landing wheels fitted with comparatively low pressure tyres.

Then there are the frequent charter services and the usual light aircraft operators come and go from Harewood.

It would have been of added value if the Average Least Dimension of the sealing chips had been given. I remember that the chips at one part of the work had an A.L.D. between 0.35 and 0.40 inches and the rate of road oil application was slightly greater than would have been the case on a road. This decision was made because of the lack of "kneading" action as against that provided by the very much greater frequency of traffic on a road.

It could be that the time is coming when the motorist will press for the same type of surfacing on roads, that is, an orthodox prime coat followed by a road oil seal with chips locked in and just covered with a fine grade of plant mix. A light tack coat is applied just ahead of the plant mix. The merit of this surfacing for highways would be that the durability of the road oil seal would be retained, while at the same time the smooth but reasonably non-skid surface would be provided. There is no doubt that where traffic counts are reaching 3,000 or 4,000 vehicles a day, the flying chips in the early stages of the seal are not very pleasant and may not be tolerated much longer. Therefore, not only Aerodrome Engineers are interested in the Harewood and Rongotai bituminous surfacing.

Photographs and metal grading charts are to be seen at another part of this publication.

THE REPAIR OF ISOLATED SURFACE POTHOLES

By J. F. Henderson
and H. A. Grigg

The isolated surface pothole is a phenomenon associated with the road surface which appears apparently without reason under any condition of traffic intensity, surface structure or climate.

The mechanics of certain causes of surface potholes have been discussed in recent technical literature but these are not to be taken as covering the whole field of potholing. Everyone associated with highway maintenance work no doubt has his own theories as to why potholing takes place just as most people have their own preferred methods of repair.

Potholes may be a symptom of structural weakness caused by many differing factors, or they may be an isolated inexplicable occurrence.

Considering the completed road as a field laboratory, the pothole, if studied as it should be, can give a valuable guide as to the quality of the road structure itself, of the materials used, and of the load bearing capacity of the existing pavement.

No one should repair a pothole without having closely investigated the surrounding area to which the pothole is related. It may be found that the pothole's existence is related to materials, to soil conditions, or to traffic conditions etc., and the repair carried out should be such as will not be affected by such of these factors as is held primarily responsible for its birth.

Potholes unattended - like Topsy - just grow, until finally - like rabbits - they multiply rapidly and the highway engineer is faced with a costly strengthening programme which could possibly have been avoided by correct and suitable remedial measures.

The pothole problem can be divided into two: (a) repair, and (b) remedial measures which have for their purpose the prevention of potholing. For instance, a surface where scabbing of chips is prevalent, or where the bitumen through hardening is likely to develop cracking, could be treated with MC_2 or MC_3 and 1/4" - 1/8" chips before the Winter in order to seal the surface, thereby removing incipient causes of potholing and failure, and gaining a further period of use for the existing surface.

It is not the purpose of this article to discuss remedial measures but rather to deal with the repair of the isolated pothole.

Repair of potholes may be either of a temporary or a permanent nature depending on the climatic and traffic conditions which exist. Temporary repairs should be such as can readily be made permanent.

The attached schedule, based to some extent on repair methods in the Otago District should be of interest to others who doubtless have differing methods.

The following are some guiding principles in regard to potholes, unfortunately difficult to put into practice:-

(1) Surfacemen must not fill potholes with any muck alongside the road. If possible, non-plastic graded material such as is usually available on the edges of the metal course should be used.

(2) Highway section maintenance foremen or overseers should patrol the whole length of their sections regularly. They should carry with them a small supply of patching material and be prepared to carry out isolated repairs themselves. If potholing is frequent the mobile repair gang should be called out.

(3) Mobile gangs should work to a plan, prepared by overseers, of both repair and remedial measures, so that the whole section is covered regularly.

(4) Overseers should carry out walk-over surveys of their sections and keep adequate records of surface conditions.

(5) In all patching, emphasis is placed on the retention or restoration of a smooth surface and the prevention of leakage of water through surfacing.

These elementary precautions can be achieved only by constant and critical attention by the officer-in-charge of highway maintenance and the intelligent co-operation of the officer-in-charge of the patrol gang.

REPAIR OF POTHOLES

CONDITIONS	TRAFFIC	TEMPORARY REPAIR	PERMANENT REPAIR	REMARKS
Freezing	All	1. (a) Fill with top course mixture, well tamped. (This will freeze up with road and maintain good surface till thaw commences).	1. After thaw has ceased, remove temporary filling, together with any loose or unsound top. (a) If existing surface 1st coat seal - fill with well rammed top oourse and seal with tar and similar chip to existing.	It is essential that temporary filling material be specially selected. The use of plastic materials leads to quick breakings of surface during thaw.
			(b) If existing surface 2nd coat seal - fill with clean, graded premix, well rammed and rolled to maintain surface levels, followed by application of bituminous emulsion and grit within 24 hours.	Premix should consist of clean graded 1" or 3/4" to 3/8" mixed with Rapid Curing Bitumen (RC_2) made in a concrete mixer or bought ready made and stored until the solvents have dried out.
Wet	Light	2. (a) As in 1 (a)	2. When conditions suitable, (a) as 1 (a) above, or (b) fill with well rammed small chips and penetrate with emulsion provided depth does not exceed 2".	The use of plant mix alone for any repair is not recommended except as a temporary measure to give relief.
	Heavy	(b) Square up shape, fill with premix, topped off with a little plant mix.	(c) Seal with emulsion and grit during first fine spell	
		(c) Fill with lean mix, well compacted concrete using rapid hardening cement	(d) as 1 (b) above. (e) Seal with emulsion and grit when conditions suitable.	

CONDITIONS	TRAFFIC	TEMPORARY REPAIR	PERMANENT REPAIR	REMARKS
Dry	Light	3. Permanent repair only should be made.	3. As 1 (a) or 1 (b) or 2 (b).	Where traffic is light, potholing being infrequent should be permanently patched in the first instance.
	Heavy	As for 2 (b) or 2 (c) above	Repairs must be carried out during off-peak hours when all temporary repairs should be examined and where necessary removed and treated as for 1 (b) above.	Where traffic is heavy, essential that good running surface be maintained which requires some quick temporary measure followed as possible with permanent work.

In all types of repair maintenance of smooth running surface is prime requirement as also is prevention of moisture entering hole and extending zone of weakness.

COMMENT

By F. M. Hanson

Roads and road surfacings are so various, temperature and climatic conditions of New Zealand extend over such a wide range, and other conditions are so numerous, that a paper on pothole repairing was not an easy assignment. Nevertheless some most helpful information has been set out for the guidance of maintenance engineers.

In the main there are two classes of pavement failures which lead to breaks and potholing. Firstly there are the failures originating in the subgrade, and secondly, there are the potholes which result from some deficiency in the pavement itself. It is rather this latter condition generally giving rise to isolated potholes on which Mr Henderson was asked to write. Although referred to as isolated, the potholes may occur in quite considerable numbers almost overnight.

I would emphasise a statement made in the paper to the effect that no one should repair a pothole without having closely investigated the surrounding area to which the pothole is related. In other words, make a correct diagnosis before attempting repairs. Those breakups and failures originating in the subgrade are dealt with in some detail on Page 58 of my report on "Roading in Tasmania".

To quote from "Roading in Tasmania" - "even a single pothole can be very annoying and troublesome to motorists and the engineer should ever be on the alert to carry out effective patching without delay. An engineer is not judged by the miles of unblemished roads which he builds, but rather by the potholes which are left unpatched. Modern traffic requires smooth and unbroken roads and it is for the engineer within his physical and financial resources, to ensure by careful organisation and engineering that the motorist gets this service".

VERTICAL SAND DRAINING TO STABILIZE TIDAL MUD AT GORDON ROAD INTERSECTION

By R. R. Parsons
(Abridged)

(1) HISTORY AND REASONS FOR USING SAND DRAINS

At the beginning of 1957 the Ministry of Works, on behalf of the National Roads Board, undertook the construction of the first portion of the Northcote-Albany Motorway which forms in effect the northern approach to the Auckland Harbour Bridge toll booth area.

Included in this motorway were traffic interchanges to give access to the Northcote-Birkenhead area and to the Takapuna area.

The location of the Northcote-Birkenhead connection was fixed by the necessity to connect to Onewa Road Main Highway, the main traffic route serving the area, by means of Gordon Road which is a direct continuation of the highway.

The precise location of the connection was fixed within fairly close limits by the general line of the motorway which could not be materially varied on account of the layout of the adjoining toll booth area, the inability to shift the connection southwards nearer the Harbour Bridge owing to the necessity to retain the minimum length of taper in the approaches to the toll booths, and the inability to shift the connection northwards on account of the proximity of high land closely built up and the indirect approach to Gordon Road which would result.

It was also necessary to design a form of interchange which could, if necessary, provide for a causeway to connect Bayswater and Devonport direct to the motorway at this point.

This causeway would approach the motorway from the east.

Unfortunately the area in which the interchange had to be located had a foundation of soft marine muds of varying depths overlying fairly firm clays and mudstones.

From the investigations it was evident that no problems would be met with in placing the ramps to the interchange on the Gordon Road side of the motorway but that considerable difficulties would be experienced in placing the higher portions of the Ramp on the seaward side of the motorway, where upwards of 28 feet of filling and pavement had to be supported on soft mud varying from 30 feet to 55 feet deep.

Two alternatives to overcome this were considered -

(1) To build a bridge some 500 feet long on the curved ramps, designed in such a way that the future connections could be made.

(2) To use vertical sand drains to consolidate the underlying mud to enable the use of a 200 feet long overbridge over the motorway (which could be built on the straight) and approach fillings.

The first alternative was costly and not very satisfactory in the matter of designing a structure which could conform now to the grades and superelevations of the semi clover-leaf design and permit of considerable alteration when the full clover-leaf was developed.

Further investigation of the sand drain proposal was decided on.

Drilling Investigation

A drilling programme was commenced to give a complete coverage of the area. The drilling was carried out from a pontoon by means of a rotary boring machine. The majority of cores for visual classification obtained in the soft clays were taken by means of an open core barrel with no water circulation and the firmer clays, sand stones and mud stones by means of open barrels and triple tube barrels with normal water circulation. Recoveries on the whole were very satisfactory, although the softer mud was very difficult to retain in the core barrels.

The preliminary work was centred around the flyover area where the flyover structure was to be located. Owing to a considerable depth of mud at the bridge site, the drilling programme was extended seawards also, parallel to the motorway such that the clover-leaf junction was fully covered.

In general, it was determined that an ancient valley infilled with modern sediments crossed the motorway some chains southwest of the proposed flyover and then changed direction to the northeast to follow along almost parallel to the motorway. The thickness of the soft silty clay was approximately 60 feet in the deepest portion of the valley.

The logs of the bores enabled a plan to be made showing the contours of the bottom of the mud. This plan was the basis of estimating the footage of sand drains required.

Following the initial investigations undisturbed samples were obtained to determine the properties of the soft marine sediments. Samples were taken with special sampling tubes, 4" in diameter and 2 feet long, and having a sludge barrel on the upper end. Before sampling, the cased borehole was washed out to within 6" of the bottom of the casing. With an attached suction line, the sampling barrel was pushed into the soft clay, twisted and withdrawn slowly as a small suction was applied. The suction was to assist

in holding the sample in the tube as no core catching device could be used. The core barrels were sealed and transported to the laboratory for testing. The samples were then prepared for triaxial and laboratory vane shear tests, consolidation tests, permeability tests, natural water content, mechanical analysis and Attenberg Limits.

The first sampling bore was largely to determine the properties of the soil and also to ascertain whether vertical sand drains were applicable to the project. The two further bores were taken as the work proceeded on the working platform.

In addition to the Laboratory work mentioned above, a series of field vane shear tests were carried out. The apparatus used was similar to that described in a paper by Newland and Allely.

(2) GEOLOGY

(Extracts from a paper prepared by Mr E.J. Searle of Auckland University and published in N.Z. Journal of Geology and Geophysics, February 1959).

"The basement rocks of the Waitemata formation are a group of mid Tertiary sediments including sand stones in beds of two to three feet and mud stones in thinner sheets. On weathering, the basement rocks are converted to heavy and silty clays. The Waitemata rocks were heavily eroded in the Tertiary and Pleistocene times and were heavily sculptured during periods of low sea level accompanying period of maximum glaciation in the Ice Age. Pleistocene clays, silts and sands have been deposited on the eroded surface of the Waitemata strata and occur in extensive fills in the old valley systems carved in the older rocks. Organic matter frequently occurs in the Pleistocene deposits. Volcanic tuffs have been erupted from various centres giving a veneer of up to approximately 50 feet of material varying in colour and texture. A sketch showing the general geology of the area is appended. (Fig. 1)

The most recent depositions are the modern muds and sands which may constitute thick fill on submerged valley floors, overlying the Waitemata and Pleistocene sediments."

Mr Searle has outlined how the geological history has been dominated by changing sea levels of glacial times. Three distinct valley forms are preserved along the line of each major watercourse. They are:

1. The modern valley contained at least in two parts by modern muds;
2. The "last glaciation" valley which may be walled at least in part, by Pleistocene silts;

3. An earlier glaciation valley walled and floored only by Waitemata sediments.

The relationship is clearly shown on a map, (Fig.2) produced by Mr Searle and a probable interpretation of the bore logs in the Onepoto area is shown on Fig. 3.

(3) REPORT BY MR P. W. TAYLOR OF THE ARMORE SCHOOL OF ENGINEERING

Mr Taylor was asked to prepare a report on the proposal and kindly consented to do so.

(4) FILL MATERIAL FOR WORKING PLATFORM AND RAMPS

The Borrow Pit

Fill material was obtained from the tuff ring on the northern side of the Onepoto basin. The Onepoto basin is one of the several volcanic craters in the area, and is now infilled with recent sediments. The tuff ring overlying Pleistocene clays is scoraceous in nature, and was apparently deposited over fairly densely bushed country. Several vertical shafts, some over 6 feet in diameter were found during excavation work which had traces of charred wood adhering to the sides. This vegetation was identified as bark of the Kauri tree.

The grading of the material varied considerably from a fairly weathered volcanic clay at the surface to layers of relatively clean fine scoria separating hard layers of cemented tuff.

The plasticity index of the unweathered tuff averaged approximately 10, and the moisture content was approximately 16% to 20% and optimum moisture content was 18%.

Shear strengths of the filling in place were in excess of 1,000 lbs. per sq.ft. The bulk density on original samples was 110 lbs. per c.ft but subsequent tests have determined this as nearer 120 lbs per c.ft.

(5) SAND FOR FILLING SAND DRAINS:

The use of vertical sand drains was basically to accelerate settlement in the marine clays. The functional life of the drain itself, in order to achieve the required consolidation does not have to be greater than approximately 18 months. The function of the vertical drain is to conduct the water to the horizontal drainage course above the working platform.

A specification for the grading of the sand was drawn up and a suitable sand was obtained for the work. The sand used was a very coarse shell sand dredged from the Hauraki Gulf.

(6) SCORIA FOR MAT

Basalt scoria from the Departmental pit at Mt Roskill consisting of 2½" all-in clean crushed scoria was used for the mat construction. This allowed free passage for water, consolidated satisfactorily and prevented intrusion of the fill material.

(7) DISCUSSION OF TEST RESULTS

The main difficulty concerned with estimates of settlement is to decide upon a value of the coefficient of consolidation which is representative of the whole sand drain area.

The question now arises what values of consolidation factors should be used to predict settlements, i.e. what material is typical of the sand drain area.

As indicated in the Appendix describing sample bore 2 (the tests on sample bore 3 are of the same order) the ultimate settlement would be approximately 11 ft.

From experience in similar type of work it is considered that this figure is high and is more likely to be of the order of 6 ft as is also indicated by settlement recorded in the field.

(8) CONTROL MEASURES

(1) Piezometers.

The piezometers were placed through the working platform into the soft marine clay.

Two types of piezometers were used and a description of each is given below.

(2) Porous Pot Piezometer

A vertical section of the porous pot is shown in diagram (4). Ten of these were made from 6" x 2" x 2" coarse carborundum sharpening stone. This stone was cut into two 3" pieces and the central core removed using a diamond bit. Tight fitting rubber bungs with two brass connecting tubes passing through were then firmly secured with wire. Then the polythene tubes were fitted to the brass connecting tubes. Originally it was intended to use 3/16" polythene pipe but this was unobtainable and 1/2" pipe was substituted. The diagrams show the fittings for use with 3/16" polythene pipe. Good fitting was obtained with 1/2" polythene pipe by dipping the end in hot water and forcing it over 9/16" external diameter brass connections.

The two leads from the porous pot were taken vertically to approximately RL 5 and then horizontally across the working platform through 4" clay pipes to the gauge mounting box at the toe of the batter. The leads were then connected to klinger cocks mounted inside the box. The arrangement of parts

is shown in diagram 5 with the gauge assembly connected ready for measurement of pore pressure.

(3) Brass Tube Piezometer

A vertical section is shown in diagram 4. The tube was filled with a six to one mortar using Leighton Buzzard sand and a water cement ratio of 0.7. A single lead was attached to the tube and taken to approximately RL 5 where a fitting was attached to allow a double set of tubes to cross the working platform to the gauge box. The two horizontal tubes allow water circulation to eliminate air tending to become trapped in the horizontal section.

(4) Installation of Piezometers

The piezometers were installed in holes drilled through the working platform and the soft clay by a boring machine; casing was used to prevent the hole caving in and was withdrawn after the piezometers' tips were at the correct level.

The installation of the piezometers presented many problems. The piezometer cells and fittings had insufficient weight to hold them at the bottom of the drilled hole. The polythene tube having a larger diameter than in the original design acted as a buoy. As the casing was withdrawn so the piezometer cell and hoses lifted due to the slight friction between the hose and casing pipe.

The most successful way found to place the piezometers at the correct depth was to drill a hole 3" in diameter through the working platform and into the mud. The casing, with a loose fitting shoe on the end, was then forced down to the depth required, and the piezometer was lowered down into the casing. The steel shoe prevented mud squeezing into the casing. At the top of the casing a connection was attached such that a small air pressure could be applied. As the casing was gradually lifted a small pressure was applied sufficient to remove the shoe from the end with the assistance of the mud squeezing around it. The casing was lifted approximately 2 ft at this stage and the compressor was disconnected. By this time the mud had closed in on the piezometer tip and held it firmly in position. The casing was then completely withdrawn and the hole sealed with a mixture of bentonite and sodium silicate. This mixture was pumped down the hole after having been mixed in a very fast paddle blade mixer. The grouting hose was gradually lifted and the hole was filled completely with the bentonite mix. The piezometer hoses were pumped clean to ensure that no dirt or mud was blocking them and taken horizontally through the working platform to the toe of the proposed batter. The double tubes allowed free circulation of water to remove as much air as possible. The cocks were left open for some time after

installation to allow the apparatus to settle down.

In some cases sand was placed around the piezometer tip but considerable difficulty was found in getting the sand down the hole. The sand appeared to bridge in the small hole and it could not be determined how much sand actually went round the piezometer tip. The sand could not be placed in the casing as when the casing was lifted the sand gripped the piezometer bringing it up with it. This meant that the sand had to be put down the hole after the casing had been removed and in many cases it was fairly certain that the soft mud had flowed in round the piezometer tube before the sand could be placed.

(5) Gauge Unit and Measurement of Pore Pressure

Three gauge units were made up using + 30 - 30 lbs/ sq.in. bourdon gauge. The unit was filled with water making certain that all air was eliminated. To measure pore pressure the gauge unit was screwed into the klinger cock in a piezometer box. To obtain a water-tight connection a washer was placed inside the cock and prior to screwing in the gauge water was poured into the cock to fill the air gap. The apparatus ready for measuring pore pressures is shown in diagram 5.

The upper klinger cock was opened to determine the zero gauge pressure reading. This is partly affected by atmospheric pressure but largely by the position of the gauge which reads very close to zero in an upright position. In the position shown in diagram 5 the gauge showed a zero error of 1 - 1.5 p.s.i. The lower klinger cock was opened to release the pressure built up by screwing the gauge unit into the cock, previously filled with water. The top klinger cock was then closed, the klinger cock connected to the piezometer lead opened and the gauge pressure read. When high gauge pressures could be anticipated the Jenkins gate valve was screwed in and the gauge pressure built up to 1 or 2 p.s.i. below the estimated pressure before the klinger cock connected to the piezometer lead was opened. This procedure ensured that there was no loss of gauge pressure due to compression of air in the gauge unit.

(6) Control Levels

Timber plates were placed on the surface of the working platform at the chain pegs and at offsets of 20 ft on either side of these.

These plates were 2 ft square and made up of 4" x 2" timber.

4" x 3" timber uprights were carried up from these plates as filling proceeded and levels taken at points on these a known distance above the plates.

At the same time levels were taken on an adjoining length of filling over mud where no sand drains were installed.

(9) CONSTRUCTION

(1) Working Platform

Prior to the drilling of the sand drains a working platform was placed over the area.

The slight upwards bulge under the fill area was to minimise the dished effect which would result from settlement under the weight of the filling to be placed.

Compaction in the lower layers near mud level was by means of bulldozers and scrapers and the upper layers were compacted with Tournapackers and heavy rubber tyred rollers.

Shear failure continually occurred along the edge of the platform during placing allowing the fill to displace the soft mud at the surface.

Bores carried out after the platform had been placed showed that the fill penetrated from 4' to 8' into the mud with a general average of 5 ft.

The displaced material built up as a mud wave ahead of the toe of the fill and gradually increased as the fill was pushed seawards.

This mud wave remained in a very fluid condition and extended approximately 200' in front of the fill in the latter stages.

This mud wave had to be kept moving and in some cases fill was placed up to the crest of the wave before forward movement was obtained.

In some cases failures of a slightly larger nature occurred. These failures were typical examples of slip circles.

(2) The Method of Placing this Working Platform

Fill material was delivered from the borrow pit by means of rubber tyred self-powered scrapers which were push loaded after the material had been ripped. The general method of construction was that the scrapers unloaded at the tip head and the fill was pushed forward at low tide and gradually increased in height as the tide rose.

(3) Experimental Sand Drains

Following the completion of the working platform the sites of the sand drains were positioned as shown on plan F attached in a triangular pattern at 10 ft centres. This plan also shows the bottom levels of the completed drains.

Three experimental drains were sunk before the contract was let using a hired rig.

It was decided not to drive hollow capped casing into the mud as experience on previous work where piles were placed

by grout intrusion methods indicated that this would smear the surface and affect its permeability.

In fact on the particular work referred to some piles were placed by driving capped casing and in these there was practically no escape of grout into the surrounding country; whereas others were bored before placing the metal and grout and in these there was a loss of 50% of grout into the country.

While this is an extreme case it indicates the effect of surface smear. Our experience indicated that the best method of placing the drains was by drilling with a rotary auger through the working platform and in the mud to place 18" diameter casing and deepen the drains by means of a percussion drill using a special T section bit fitting inside the casing. Basically the equipment was used to slurry the mud. At frequent intervals a tube fitted with a hinged flap was lowered to remove the slurry, which was discharged into a large steel container and removed from this by means of a vacuum tank which discharged on the tidal area.

The casing was gradually eased into the mud and the procedure repeated, the water for slurrying the mud being introduced after each bailing operation, until the required depth was reached.

In general the length of casing used was 20 ft. the country below this level being excavated without casing. In some instances casing lengths of 40 ft were necessary but generally the mud below 20 ft stood satisfactorily until charged with sand.

For the bulk of the drain installation the hole through the working platform was stopped some feet short of mud level and the casing was pushed down to its full extent prior to boring through the mud to minimise any chance of mud flow into the holes.

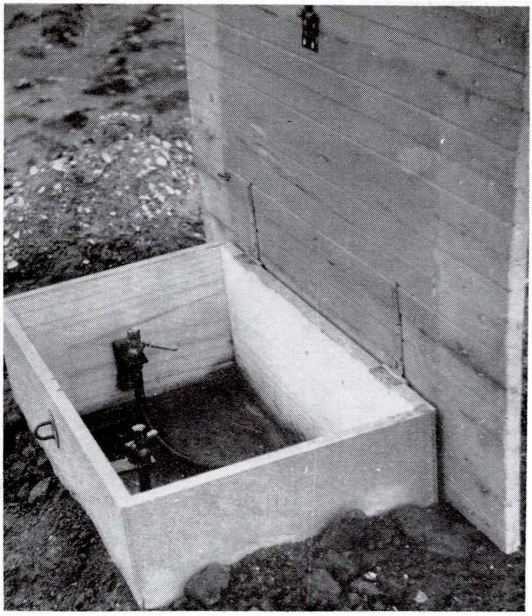
(4) The Filling of the Sand Drain

Various methods of placing the sand in the drains were tried.

Firstly the hole was dewatered and the sand placed in the dry, but there was danger of wall collapse during dewatering and the sand tended to compact in the end of the casing and act as a plunger to pull in the walls as the casing was vibrated out.

Finally the most satisfactory method was found to be to place the sand through the water as follows:-

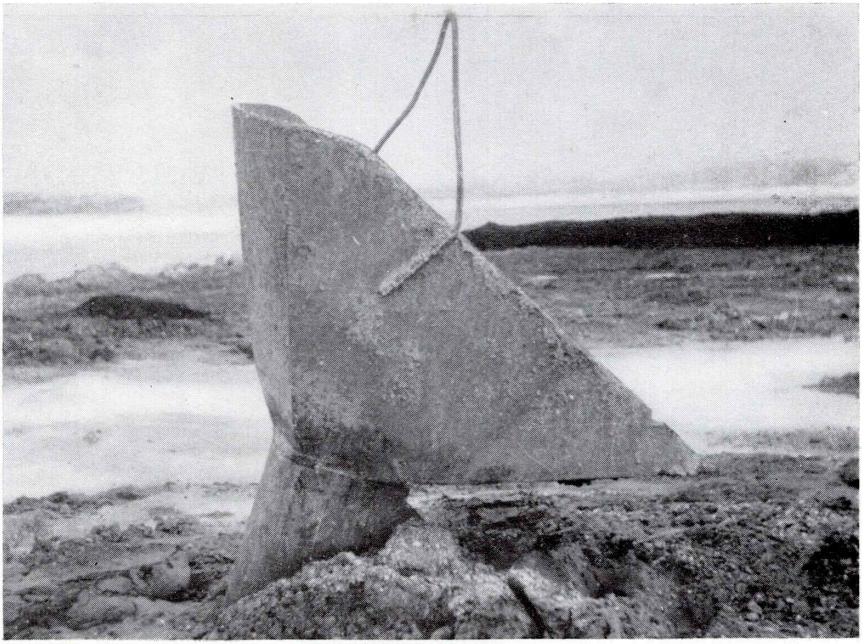
The casing was left in position after the drilling operation and the sand introduced to the well by means of a hopper. A front end loader was used to transport the sand



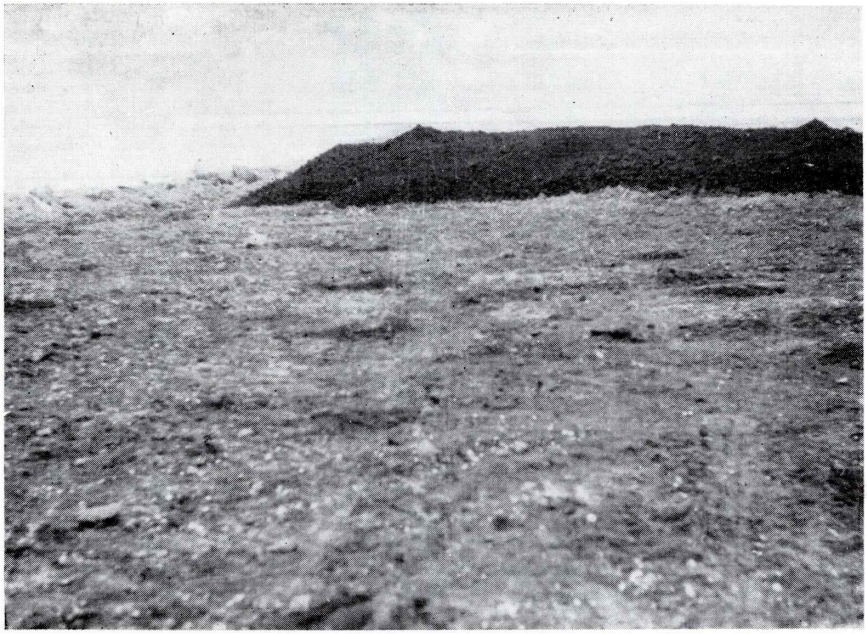
Views of

NORTHCOTE-ALBANY MOTORWAY

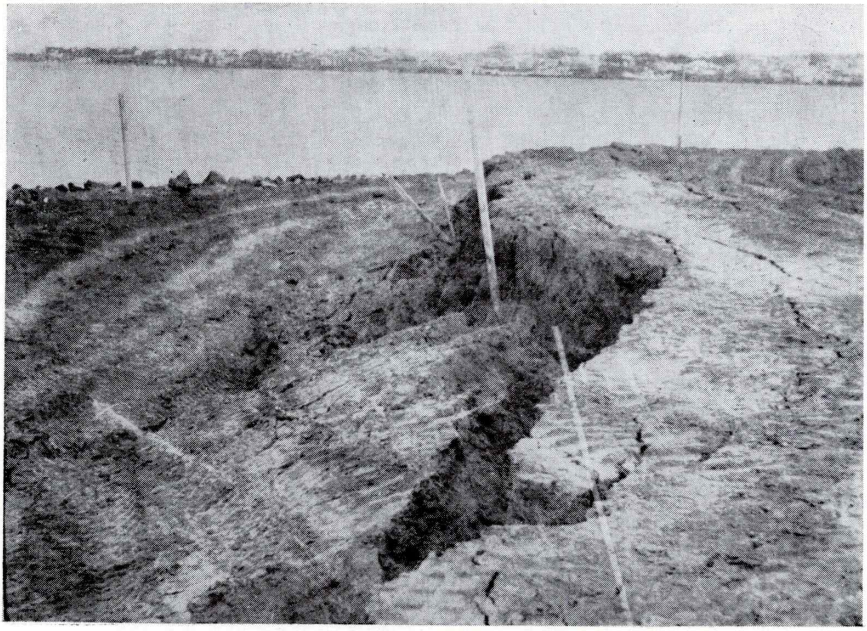
Piezometer box with cocks



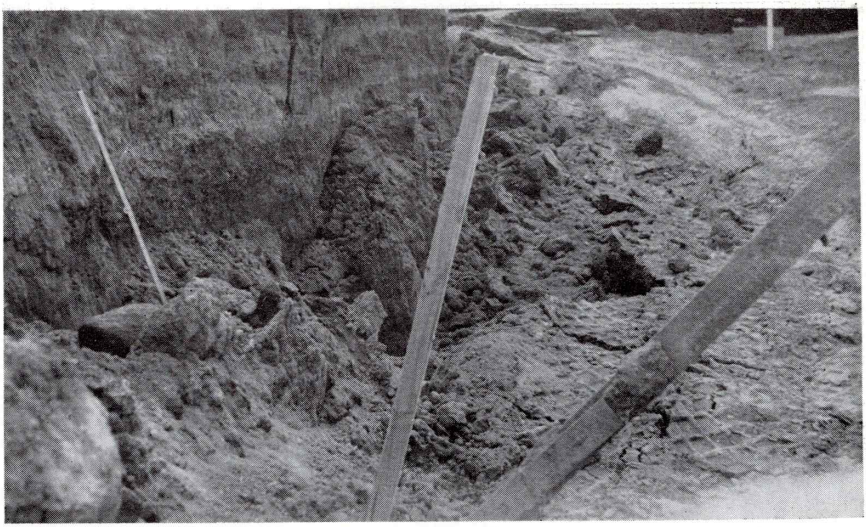
Hopper for loading sand into drains



Lines of drains in front of scoria mat

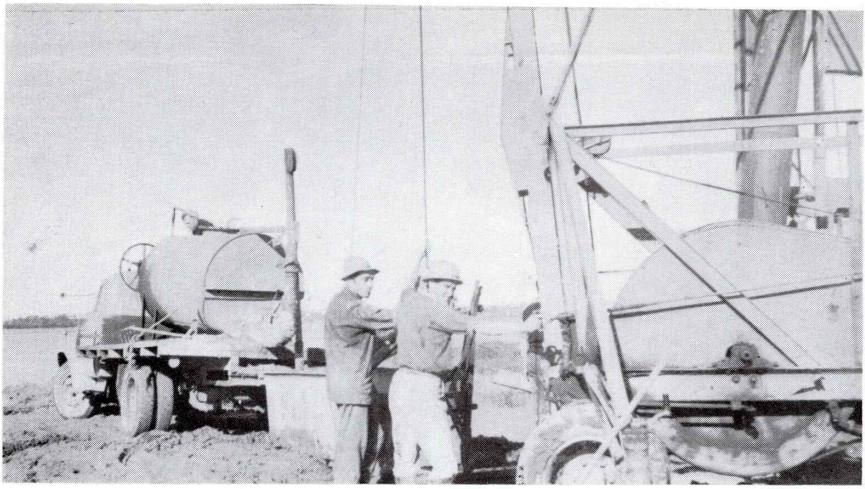


General view of major slump

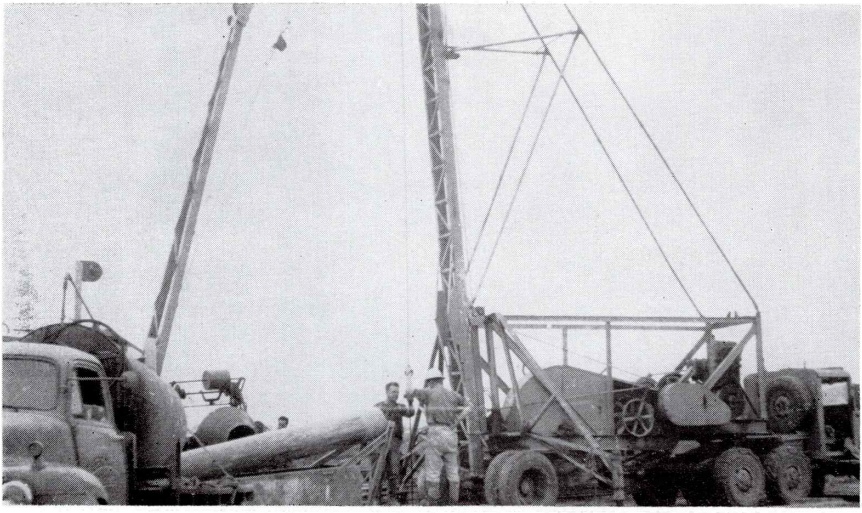


View of major slump

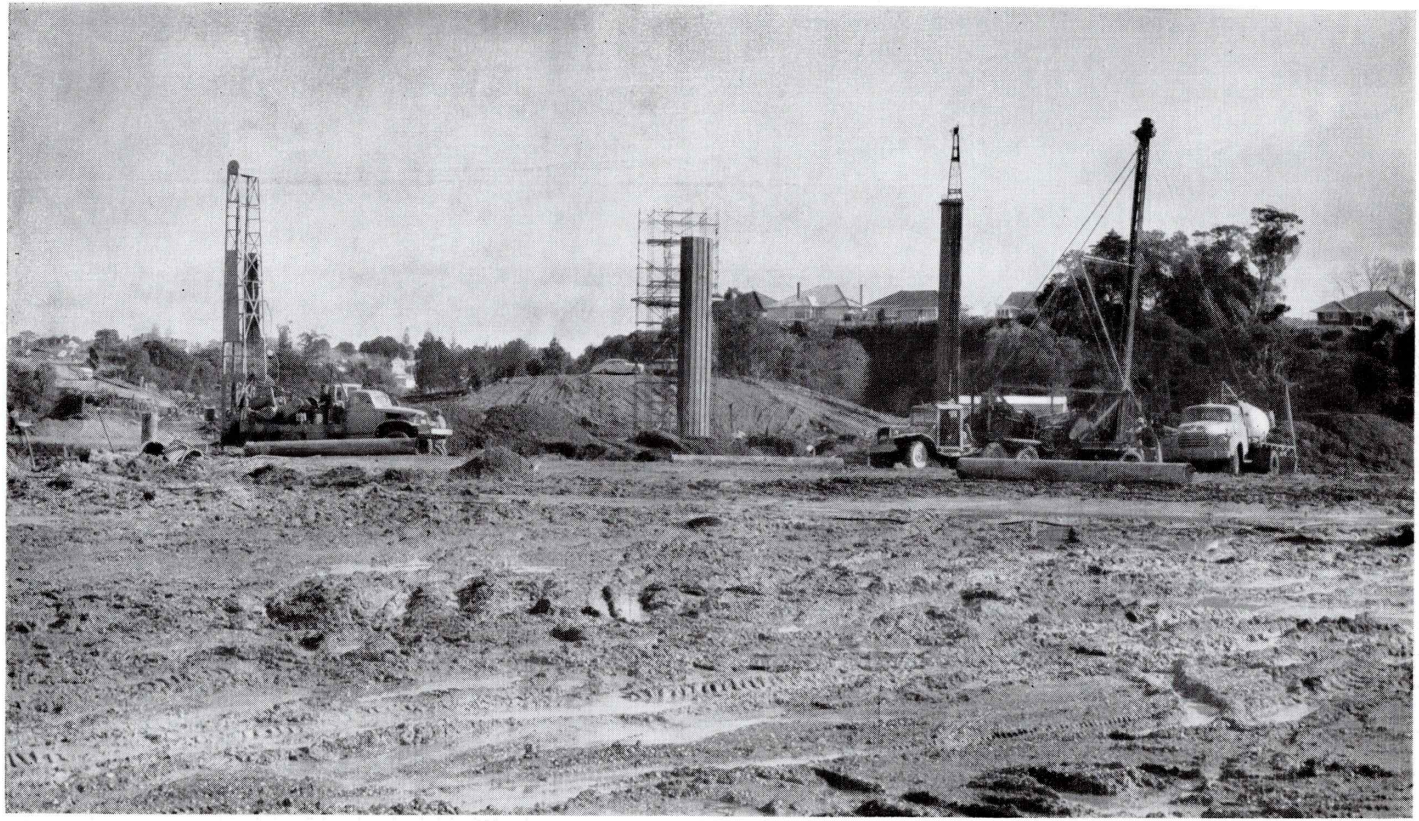
Shear cracks at slump



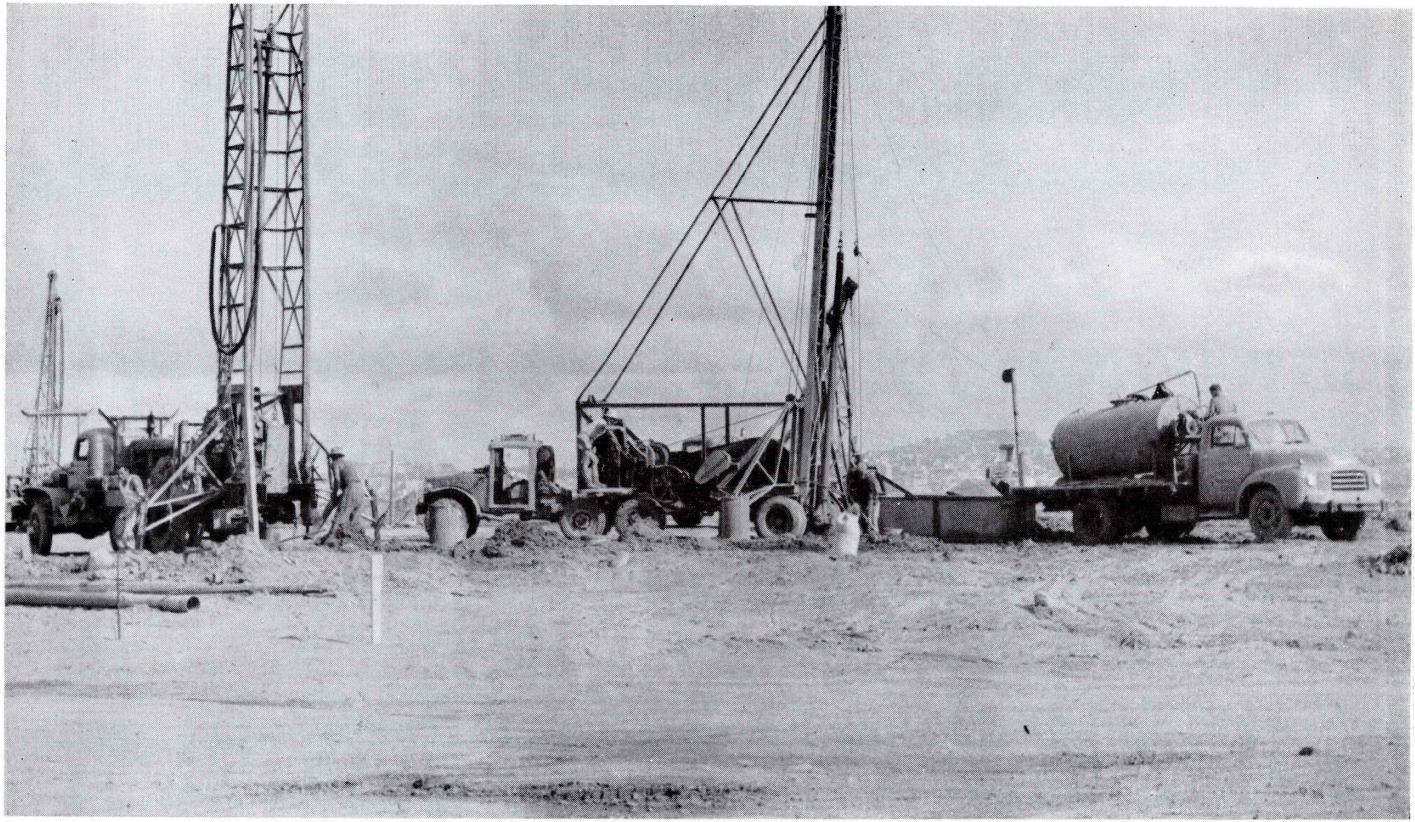
Drill rig with sludge container and vacuum tank



Discharging sludge bailer into container

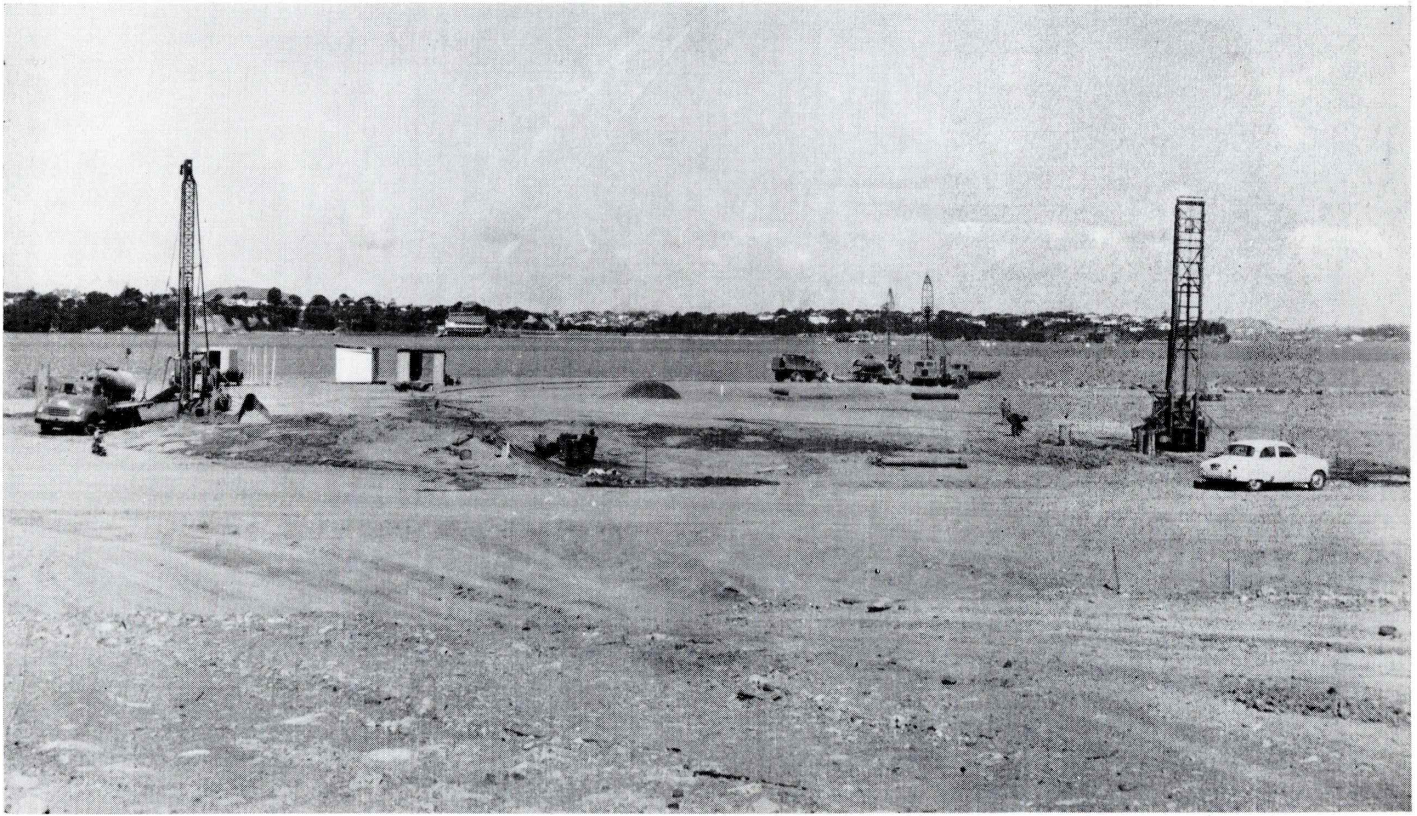


Wet conditions on working platform in winter *Photo by P. H. G. La Vie*



Close up of drilling rigs with sludge container and vacuum tank

Photo by P. H. G. La Vie



Rigs in operation at start of sand drain drilling

Photo by P. H. G. La Vie

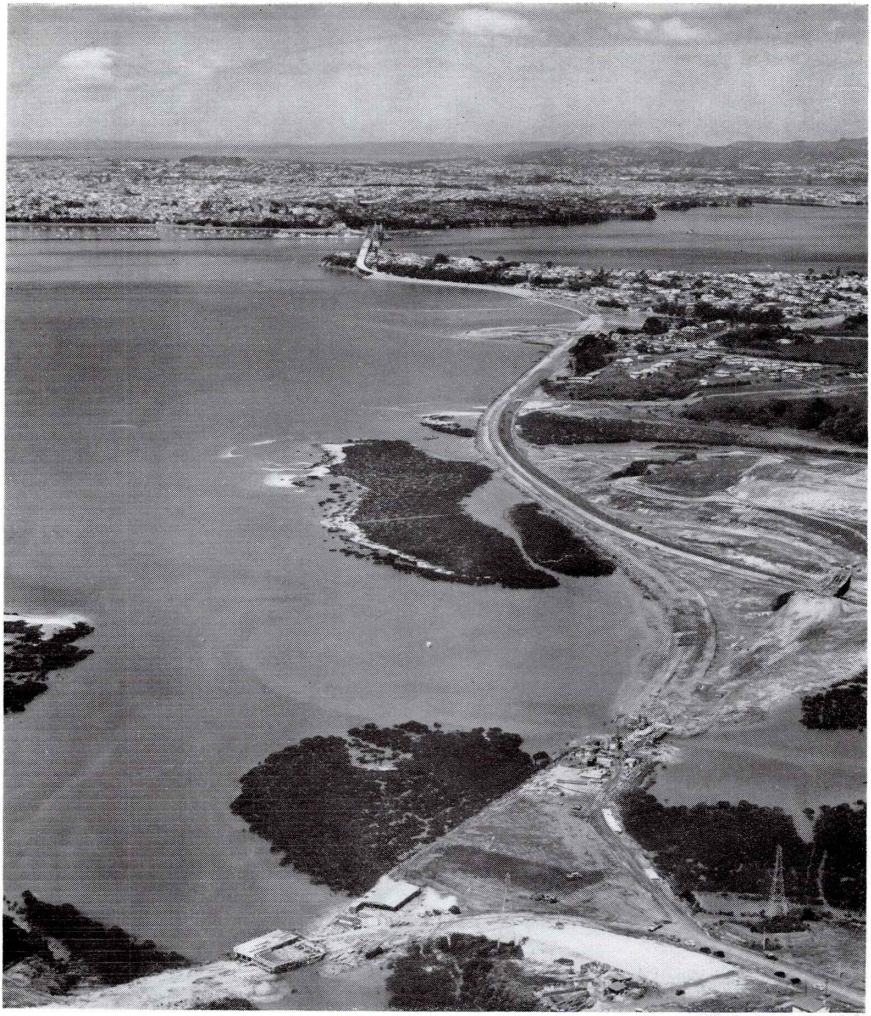
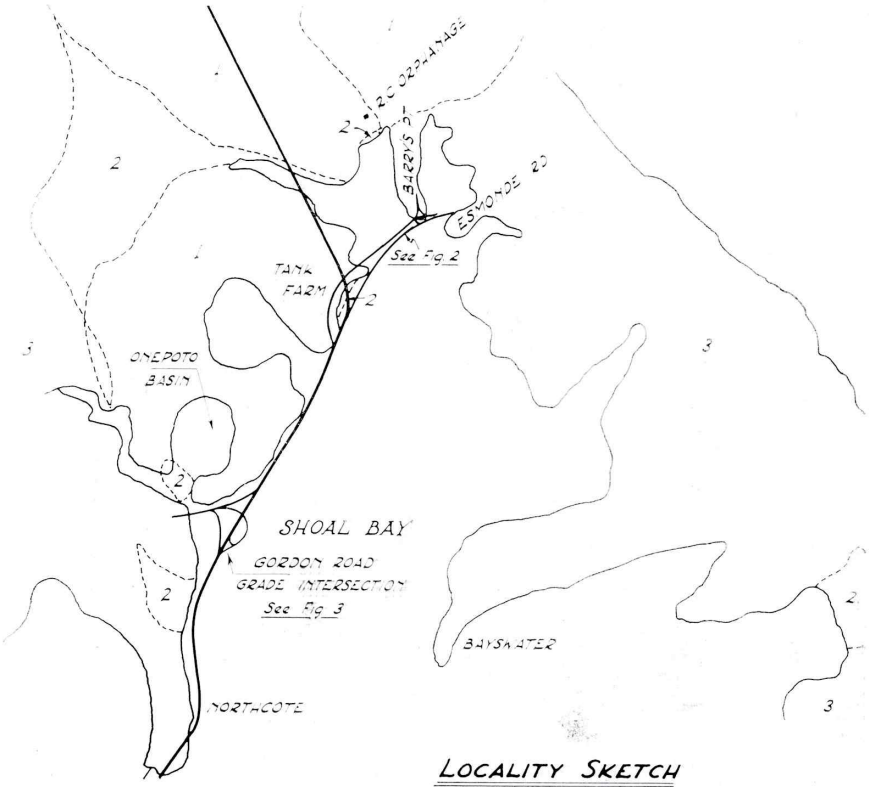


Photo by Whites Aviation

General view of motorway and harbour bridge. Sand drain area in centre towards bar

View of the Gordon Road interchange under construction

Photo by Whites Aviation

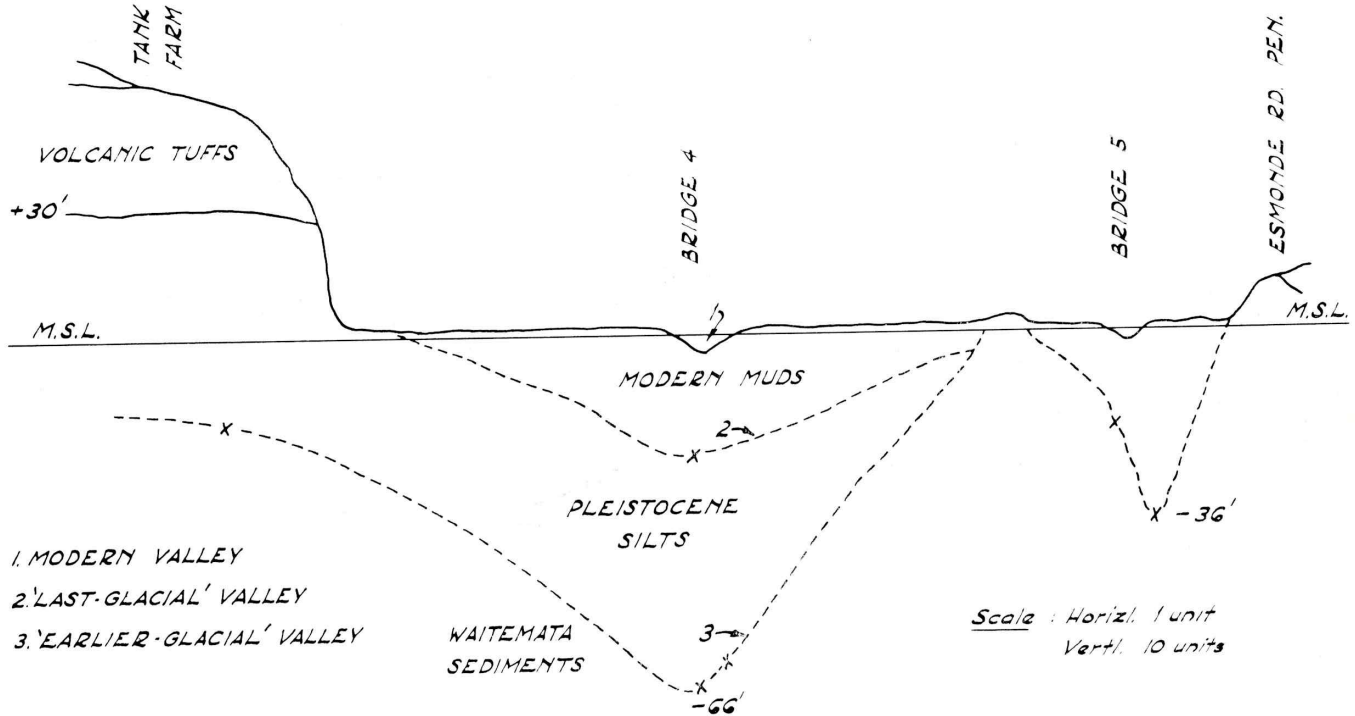


LOCALITY SKETCH
NORTHCOTE - ALBANY MOTORWAY

0 .2 .4 .6 .8 1 mile
Scale of Miles

1. RECENT VOLCANICS
2. PLEISTOCENE SILT
3. WAITEMATA SEDIMENTS

FIGURE 1



CROSS SECTION

FIGURE 2

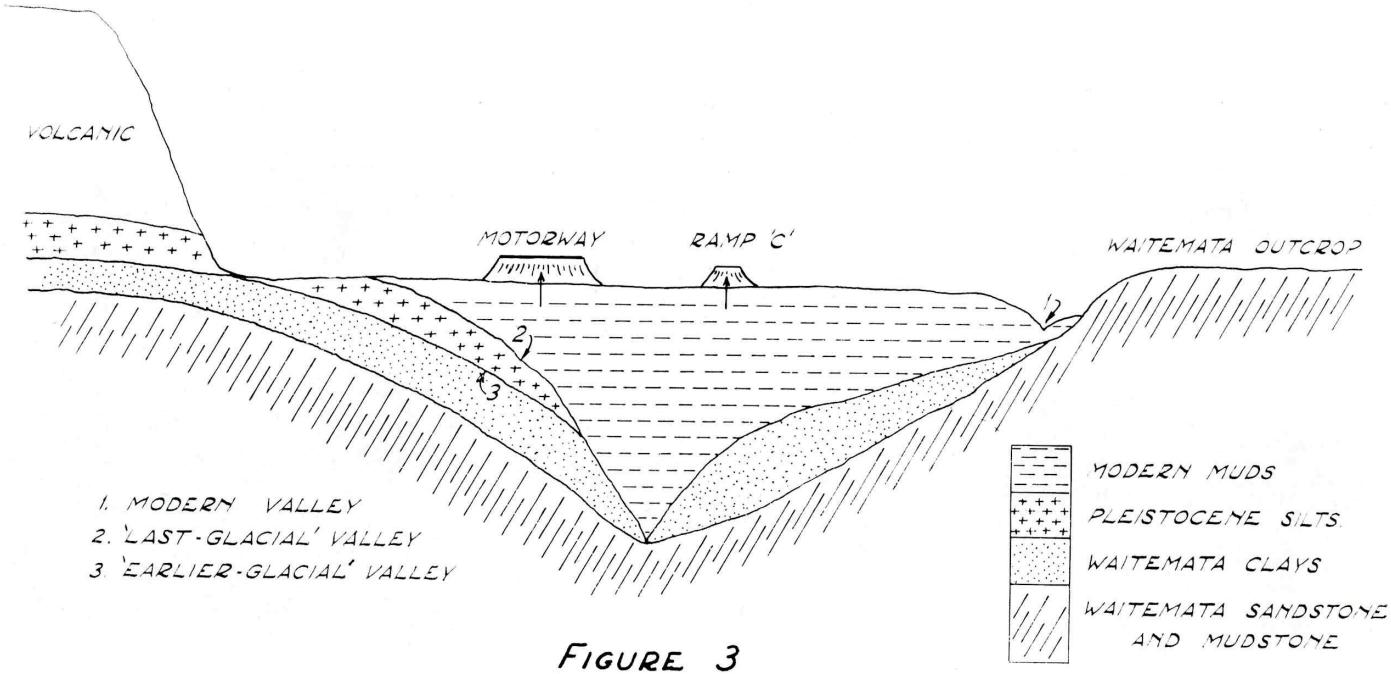
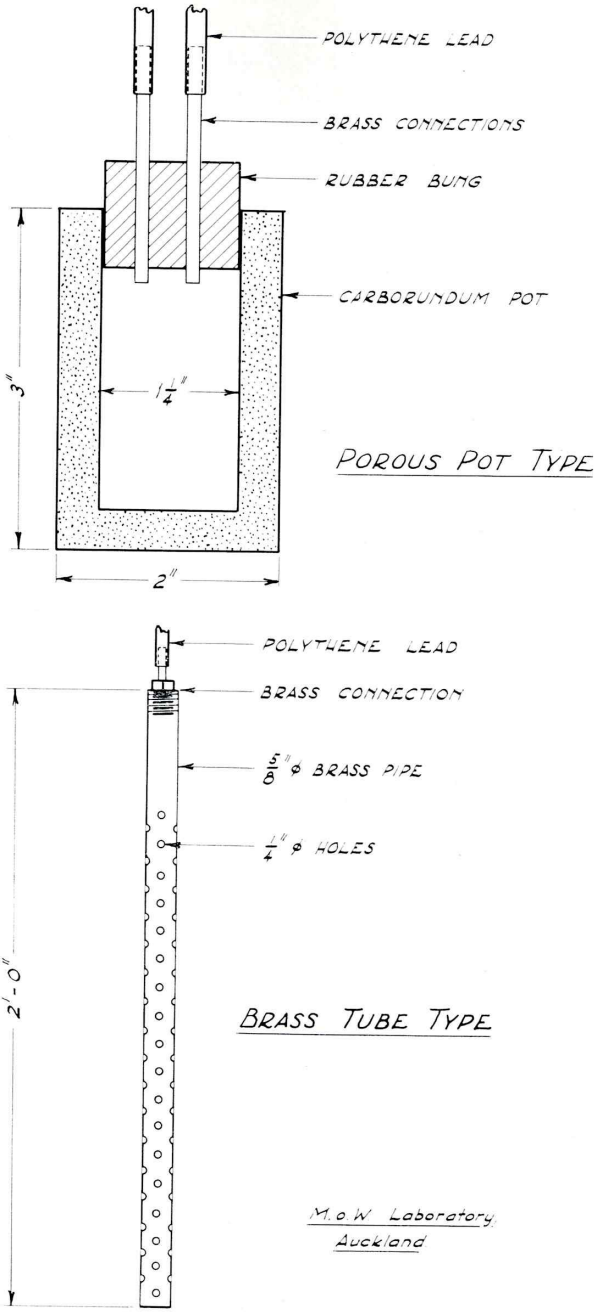
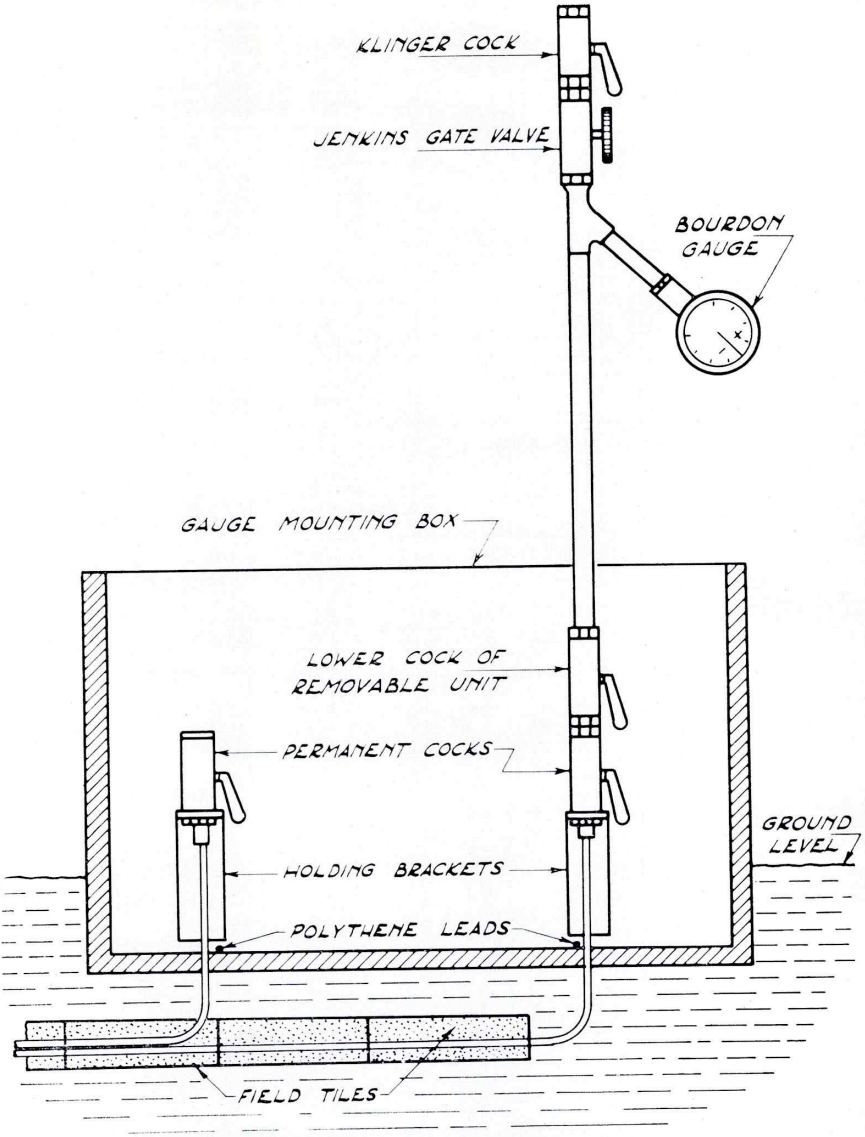

VOLCANIC
MOTORWAY
RAMP 'C'
WAITEMATA OUTCROP
1
2
3
1. MODERN VALLEY
2. 'LAST-GLACIAL' VALLEY
3. 'EARLIER-GLACIAL' VALLEY
MODERN MUDS
PLEISTOCENE SILTS
WAITEMATA CLAYS
WAITEMATA SANDSTONE AND MUDSTONE

FIGURE 3



PEIZOMETER TYPES

FIGURE 4



DIAGRAMMATIC SKETCH OF RECORDING STATION

M. O. W. Laboratory - Auckland.

FIGURE 5

from the stockpile to the hopper. As the sand was fed from the hopper considerable water was displaced carrying a quantity of fine sand with it. The coarser particles sank rapidly and the finer material settling more slowly. Some segregation was apparent in a test drain made of split casing standing vertically on the ground. After the casing had been filled it was placed horizontally and opened to observe segregation. The amount of sand placed in the test drain at each operation was smaller than in the actual sand drains. Normally each hopper load of sand filled approximately 3 feet of drain whereas in the test drain the quantities were roughly one-half of this amount.

Samples of the material were taken 18" apart on the test drain and a mechanical analysis taken.

In the sand drains themselves it is thought that segregation would only take place in a small band at the junction of each load of sand. A small percentage of coarse material would fall rapidly at the commencement of filling but at the cessation of filling fine sand would gradually settle out. As the sand drain is expected to function efficiently for approximately 18 months the small amount of segregation however is considered a minor factor.

A more satisfactory method would be to place the sand through water in a bottom discharge bucket, but this would slow up the work materially.

(5) Tenders

Tenders were called for the sand drain work on 14 December 1957 and a tender from the Gilberd-Hatfield Pile Coy was accepted on 10 February 1958 with a completion date of 10 May 1958. The contract schedule was as follows:-

1. Drill 680 only 18" diameter bore holes down to top of clay, average depth 50'. Case where necessary and remove materials	32,000 lin.ft. @ 9/-	£14,400
2. Fill the 680 bores in item 1 with sand from stockpile and clean up.	32,000 lin.ft. @ 3/-	4,800
3. Building & Plant, Establish and Remove	Item	625
	Total	£19,825

Actual completion date was 18 July 1958.

The sand used for filling the holes cost 24/- per cubic yard on the site and 3,500 cubic yards in all were used.

The scoria for the mat cost £1 per cubic yard delivered and 5,700 cubic yards were used.

This, of course, reduced the fill material required over the sand drains.

The Contractor provided five motorised truck mounted drill rigs, together with pumps, containers, vacuum tank and associated equipment and worked two shifts on the work.

In spite of this, bad weather and other reasons delayed the completion until 18 July 1958.

Unfortunately owing to the urgency of the work (the whole motorway and associated works had to be completed and in use by early 1959) operations had to be carried on in the winter. A good deal of rain fell which, combined with the water discharge from completed drains and from drilling operations, kept the work area wet. A series of open drains was installed but some softening of the work area was unavoidable.

The volcanic fill material in the working platform was very good and stood up to the heavy machinery quite well. Had clay been used conditions would have been impossible.

The softening of the work area caused some damage to piezometer installations. On the conclusion of draining operations the Contractor cleaned off top slurry and disturbed filling to a depth of 9" to 12" and hand cleaned the top of each individual sand drain placing a small mound of clean scoria over each.

The area on completion, owing to settlement and disturbance was almost flat and the scoria mat was thickened to 3 ft in the centre of the fill area and was 2 ft deep at the edges.

On completion of the sand drains water continually rose to the surface from them and although individual drains could not be observed after the placing of the mat and filling water is still seeping out from the edges of the mat.

Appendix V shows settlements.

Appendix VI shows piezometer readings.

The large slump which occured on 8 October 1958 extended in to the centre line of the filling and was between pegs 35 and 37 with tension cracks extending almost to 34 and 38.

Movement in a seaward direction was not observed as no reference pegs had been placed in the working platform on the seaward side of the embankment. Considerable heave was noticed at the toe which in its remoulded condition failed again leaving the toe of the slip gently sloping seawards.

It was considered that as the working platform extended to a considerable distance from the toe of the filling such pegs in the mud edge would be of doubtful value. Subsequent

experience has altered this opinion.

At this time the overbridge between pegs 2868 and 3181 was well advanced, all piers and abutments were completed and beams were in position.

Any extension of the slump would have endangered the stability of the abutment at 3181 so the level of the approach filling between the bridge and the slump was immediately lowered.

In the process of this work and as a result of the slump many of the levelling standards were destroyed.

An immediate start was made on extending the berm outside the slump to counterbalance it and this work was completed on 20 October 1958.

As the berm was being built the cracks in the slumped area were filled in and the whole of the area levelled out.

At the time of the slump the fill level between pegs 35 and 37 was not being altered but machines were passing over this area (which had been in position for a week) in order to raise the fill level between pegs 32 and 35.

Previous slumps in this type of work have always occurred at low tide (when the weight of water is removed from the mud) but this slump occurred at about half tide.

Levels taken prior to the slip show that slight excess fill had been placed at 37 and 36 chains. Failure occurred through overstressing the soil and it must be concluded that the mud was not of equivalent strength as determined by the Laboratory and field tests or the excess fill was sufficient to lower the safety factor or a combination of both above factors.

At this stage it is interesting to note that during the installation of the sand drains in some areas mud flow gave considerable trouble. The Contractor responsible for the sinking of the drains found that after the working platform had been penetrated soft marine clay flowed up the hole. The possibility of soil flow into the sand drain hole during drilling operations cannot be overlooked as any movement in the clay would tend to lower the value of the shear strength, due to the high sensitivity of the mud.

It had been hoped to trace the slip surface by boring holes to ascertain where the sand drains had been severed. In the slip area very few traces of the sand drains were found even though an extensive grid pattern was bored round each original sand drain. Detailed results of these investigations are not yet available. The pore pressure measure-

ments taken the day prior to the subsidence gave no undue cause for alarm and at this stage of the project, appeared to be working satisfactorily. The slip remains a problem of why overstressing occurred. It may be some time before an answer is provided.

(10) STABILITY

The stability of the embankment was an essential section of the investigational work. In Mr Taylor's original report reference was made concerning the loading of the area in stages according to more information revealed by a further testing programme. The design of the intersection was modified considerably and the working platform was extended such that a considerable area was reclaimed. This necessitated further stability calculations.

A considerable time was spent calculating the safety factor from the final plans between 32 chains and 38 chains. In most cases the sections investigated were at right angles to the rock wall. Stability was increased considerably by the continuation of the working platform between ramps C and D and the detailed slip-circle analysis concerned the more unstable seaward side.

The following data was used in the calculations:

1. Shear strength of fill = 1000 lbs/sq.ft.
2. Density of fill = 120 lbs/cu.ft.
3. Shear strength of mud
   0 - 20 ft = 200 lbs/sq.ft.
   20 - 40 ft = 400 lbs/sq.ft.

It was assumed that the embankment was placed up to formation level in one continuous operation. This represented the most unsafe condition likely to be encountered.

The slip circles were calculated with an embankment constructed to the centreline level without superelevation. The proposed 6 ft overlay was then to be placed above these levels.

It was realised that extreme care should be taken when formation level was reached and that further shear tests would be necessary to determine the effect of drainage due to the sand drains, before placing any overlay.

(11) MEASUREMENT OF SETTLEMENT

Levelling standards were placed in the scoria blanket such that the fill could be placed around the wooden uprights. The initial set of posts were set on the centreline and 20 ft each side of the centreline. Levels were taken periodically together with records of the height of the fill.

The results from the initial set of level pegs were not very satisfactory as the fill was placed in layers over a period of approximately six weeks. No even curves were obtained.

A failure occurred during the construction operations and many level standards were no longer functional. In addition wooden standards could not cope with heavy rollers passing close to them and many were damaged during the construction programme. Following the failure steel standards were placed as close to the scoria blanket as possible, and some at the toe of the batter. The installation of these standards was carried out during the earthworks programme and they were extended as necessary. Even steel standards were bent and suffered considerable damage mainly due to the limited manoeuvring area available for machines. The records kept on the steel standards however are fairly satisfactory and the results of the readings are discussed below.

(12) SETTLEMENT

Full details of the settlement will not be available for some time owing to the fact that the embankment is still settling quite steadily in some areas.

Settlement figures have been divided as in the majority of cases due to the long time-lag in re-establishing the standards following the failure, the figures obtained from the initial set of levels could not be tied up satisfactorily with those after the failure.

It is hoped to be able to give a series of graphs at a later date.

The most important feature of the records is the high settlement rate prior to the failure. The graph plotted for 32 chains gives a fairly close resemblance to the theoretical curve but accurate forecasts in settlement cannot be made yet, as sufficient time has not elapsed to determine the shape of the settlement graph.

Important stages in settlement have not been recorded satisfactorily. These are briefly as follows:-

1. No record of settlement could be obtained during the placing of the working platform and reference pegs on the area during sand draining operations were continually disturbed by the Contractors' machinery working in muddy conditions.

2. A limited area in the vicinity of the southern bridge abutment was used as a stockpile for the scoria blanket after the sand drains had been installed. No record of the settlement caused by the stockpile was kept.

3. The placing of the fill in layers produced an uneven loading which gave rise to unpredictable results. Sudden increases in settlement over short time periods in the initial stages of building the ramp occurred. More time between loading would have been desirable to have observed the behaviour of the fill.

4. The lack of settlement information for a period of six weeks following the subsidence.

5. Damage of levelling pegs by machines.

No overloading of the filling was carried out, as after the major slump it was considered too risky to place the additional load on the area. Further slumping may have resulted.

(13) CONCLUSIONS

(1) Performance of Piezometers

The purpose of the piezometers was to record the pore pressure in the soil surrounding the piezometer tip. The ideal condition is such that there is no flow of water in or out of the porous cell, that is, the system is completely free of gas or air. The pore pressure measured by the recording gauge situated on the working platform is actual pore pressure less the head of water from the cell to the recording gauge.

The excess pore pressures calculated enable the progress of consolidation to be followed and these figures can be compared with the curves obtained from settlement measured in the field.

The percentage consolidation as a result of an increase in loading equals the percentage of the applied stress which has become effective overburden pressure. From Mr Taylor's report a value of 0.3 has been accepted for K in the following equation:

$$C = \sigma o + K\ Pv$$

From this equation and the increase in the effective overburden the increase in shear strength can be calculated. On 15 September 1958 after 3 ft to 5ft of fill had been placed the percentage consolidation was calculated to be between 45% and 60%. The increase in effective overburden at 35 to 37 chains was equal to 600 lbs/sq.ft. The increase in shear strength of mud was taken as 0.3 of the increase in effective overburden, and was of the order of 200 lbs/sq.ft. In actual fact vane tests on the mud after the failure showed that if an increase in shear strength had occurred then considerable remoulding at some stage of the project offset the increase due to consolidation.

Several piezometers had become non-functional due to several causes. The Contractor drilling the sand drains uprooted two; these were replaced after the breakages had been located. The softening of the working platform and removal of muck by bulldozers accounted for seven, only one, number 9, being reconnected. The slip disconnected numbers 10 and 13. Only five cells are now in working order.

All piezometers in operation are blocked to some degree. This could be accounted for in two ways, (1) small particles of dirt have lodged in the unions of the pipes, (2) mud has entered the cells. The latter is more probable as the cocks were left open on several occasions to allow air or gas to escape. This would allow water to pass from the soil through the porous cell, carrying with it a quantity of clay particles. The free passage of water should not have been allowed, and the gas generated (hydrogen sulphide) eliminated by frequent flushing. Gas has affected number 5 severely. Some of the piezometers fulfilled their correct function.

The pore pressures are of value only in calculating the % consolidation values.

If the shear strength of the underlying mud had been determined on completion of the sand drains then the calculated increase in shear strength should have been reasonably accurate.

This was not done and our calculations were based on the originally determined shear values which may have been varied by some remoulding during construction.

Obviously some variation in shear values must have occurred otherwise the failure would not have happened.

It is recommended in future works that shear values be determined after sand drains have been placed and before proceeding with filling.

(2) It is too early to determine ultimate settlements and times taken for these. A further report will be forwarded at a later date in this matter.

Settlements over the slump area are unpredictable owing to the disturbance of the underlying mud.

(3) As a result of this work, it is considered that more time should be available for similar work in future, and draining operations should be carried out so far as possible in dry weather in the summer season.

(4) It is recommended that hollow casing be pushed or driven down to the full length required before drilling in the mud, to minimise mud flow into the holes.

(5) In spite of the failure, the filling is in position and the carriageway sealed in time for the opening of the Harbour Bridge.

Total settlement has not yet occurred but it appears that the larger part has occurred.

Some adjustment of the surface at a later date will be necessary as further settlement takes place, particularly at the junction of the bridge and the filling, but this should not extend over any considerable time.

(6) More time should be allowed between the layers of filling and further tests of shear strength should be made as filling proceeds.

(7) Although difficulties have been experienced in this work and the end result is not quote so good as hoped, the use of sand drains has enabled the work to be carried out, has considerably accelerated the rate of settlement (approx. 90% of the consolidation to date has been as a result of the sand drains) and has produced most of the results expected of it.

If further precautions are exercised as set out above, it is considered that the use of sand drains in this type of construction is a successful method of dealing with the problem, and I would have no hesitation in recommending their use in future work.

REPORT ON
VERTICAL SAND-DRAIN PROJECT, SHOAL BAY

By P. W. Taylor
(Abridged)

Introduction

The writer was asked by the Ministry of Works to supervise the soil mechanics test work necessary, and to prepare a report on the proposal to use vertical sand drains beneath an embankment up to 30 ft in height for the Auckland Harbour Bridge approach road, across Shoal Bay. Samples were obtained by M.O.W. using Auckland University College sampling equipment, and the tests were carried out in the Auckland University College Soil Mechanics Laboratory at Ardmore by Ministry of Works personnel, under the supervision of the Writer.

Test bores in the area had shown that Waitemata series sandstones were to be found at depths ranging up to 30-40 ft and above these were marine silt deposits. Vane tests in these deposits had shown them to be of very low shear strength, and on the basis of these tests, Ministry of Works (Auckland) had estimated that, for an embankment of 30 ft height to be stable, uneconomically flat side slopes (of the order of 7°) would be required.

The suggestion was then made that, by using vertical sand drains beneath the embankment, it might be possible to build an embankment which would still be more economical than the alternative proposal, i.e. short span bridging.

The advantages to be gained from sand-drains are:-

1. Acceleration of rate of consolidation settlement,
2. Increase in strength of soil, resulting from consolidation,
3. Reduction of porewater pressures beneath the toe of an embankment, thus increasing stability.

In addition, it is sometimes stated that sand-drains will, themselves, increase the bearing capacity of the ground. They were used for this purpose in Holland (Ref.1) with some success. It is believed, however, that any significant increase in bearing capacity resulted from consolidation of the soil, rather than from the added bearing capacity of the sand "piles".

Unless the sand in the drains is in a dense state, which is not likely in practice, the immediate bearing capacity will not be increased, and may actually be decreased, due to disturbance of the ground.

Survey of Available Literature

Since about 1936 when a Californian sand-drain project was described (Ref 2) there have been numerous papers on this subject. In 1948 further details (Ref 3) of the Californian work were given, and methods described which seem to be widely accepted. There an embankment, about 25 ft high was built on 60 ft depth of soft blue clay, using 18" and 24" diam. vertical sand drains. No details of stability estimates or strength of the clay is given, but typical specifications are included.

Ref. 4 describes the successful use of sand drains beneath a dyke, 10 ft high, surrounding La Guardia Airport, New York, on about 50 ft depth of organic silt, with cohesion of 200 to 600 lb/sq. ft and other similar works. Ref 5 gives very useful information concerning the practical details of installation of sand-drains, and observations required during embankment construction. Observations are made of settlement, and pore-water pressures, while "side stakes" indicate the imminence of any slip. The practical limits on the size and spacing of sand-drains are given as 12 to 20 in. diameter, at 6 to 20 ft spacing, and 10 to 100 ft deep. The project described is a 10 ft high embankment on 25 ft of soft organic silt.

Ref 6 includes 5 papers on sand-drain projects:-
That by Webber and Hill, describes the use of sand-drains at the toe of an embankment only, to stabilize the slope. This does not greatly accelerate settlement under the centre of the embankment.
That by McAlpin and Sinacori gives details of a 22 ft high embankment on up to 70 ft depth of soft material, with a cohesion of 200 to 300 lb/sq.ft. Side slopes were 1 to 2.

A paper by Tsien describes a 25 ft embankment on 10 to 45 ft depth of very soft organic silt. The embankment was built up to twice the required height, to hasten consolidation and the overload then removed.

Ref 1 gives a theoretical analysis of the problem with useful design graphs.

In many of the earlier projects described in the available literature, the primary objective has been to increase the rate of consolidation, and any increase in strength due to consolidation has not been essential to the success of the project, i.e. the original soil has had adequate strength, in its unconsolidated state, to safely support the full embankment. In the present case, however, the increase in strength due to

consolidation during and after construction must be relied upon to ensure final stability. In this connection, R.A. Barron (Ref 1 1948) stated:

> "The factors affecting the shearing strength are not fully understood at present; however, it is known that the shearing strength increases with a reduction of the soil pore water".

More recent papers describe projects where the initial strength of the foundation material is certainly inadequate to carry the embankment without consolidation. Also, research has been carried out to determine the anticipated increase in strength.

Although only one account of an embankment over 30 ft high has come to the writer's notice, it does appear that the method has been used with success for similar projects overseas, and on foundation materials initially as weak as, or weaker than in the case under consideration.

Test Work Performed

A set of 5 / 4 inch diameter undisturbed samples was obtained at depths ranging from 6 ft to 20 ft below the original surface. Difficulty had previously been found in obtaining such samples, and a technique in which a partial vacuum was applied to the sampling tube during extraction, was used.

Liquid and plastic limits were determined, and consolidation tests carried out. Apparent cohesion was determined using the laboratory (miniature) vane, on both natural samples, and others consolidated in the oedometer. Permeability and consolidated undrained triaxial tests were made. Details of these are given in test report No. 411.

General Method of Construction

The accepted methods of construction as adopted in U.S.A. are as follows:-

1. Placing of working platform. Filling is placed over the area to enable drilling rigs to operate. In the present instance, the working platform would presumably be above high tide level.

2. Placing of sand blanket. A minimum of 2 ft thickness of clean sand (less than 3% passing No. 200 sieve) is placed over the working platform. This allows water to escape from the sand drains. (In Auckland scoria may be more economical for use in the sand blanket and sand drains).

3. Driving of sand drains. These are invariably installed for the full depth of soft material. There are several methods of driving the drains. In some cases a closed mandrel, with a hinged bottom, is driven to the required depth and filled with sand. Air pressure is applied as the shell is extracted to prevent the sand from sticking in the mandrel. Sometimes an open-ended mandrel is driven, and cleaned out. Coarser sand is used than in the blanket (less than 3% passing No. 100 sieve).

4. Embankment construction. Filling is placed and compacted and, while laboratory tests serve as a guide, the rate of construction is determined largely by the behaviour of the soil in the field.

This is closely observed in the following ways:-

(a) Settlement of steel plates, usually placed on the sand blanket, and attached to vertical pipes, is measured.

(b) Porewater pressure measurements are made using piezometers sunk in the ground, to indicate the degree of consolidation achieved.

(c) Side stakes, placed in rows beyond the toe of the embankment indicate horizontal and vertical displacement, and give warning of incipient failure by sliding. Construction can then be slowed down until further consolidation has occurred.

5. Overload. The embankment is built up beyond the required height for a certain period, so that, when it is reduced to the required height, little or no further consolidation will occur.

6. The overload material is bladed off, and used to finish the sideslopes, and the formation is ready for surfacing.

Method of Design

There are many variables, such as rate of loading, size and spacing of drains, embankment slopes, amount of overloading, etc. so that the solution adopted may be one of many possible variations.

In this case, the total time available for construction is limited. It will be assumed that the time available, from installation of sand drains to commencement of paving, is 12 months, and that the filling is placed at a uniform rate during the first six months, and the overload allowed to remain for the latter six months. In Appendix III it is shown that,

with 18 inch diameter drains, spaced at 10 ft centres, on a triangular pattern, 70% consolidation is achieved after 3 months, if the load is applied instantaneously. Approximately the same consolidation would occur if the load were placed at a uniform rate over a period of 6 months.

The amount of overload required can then be estimated to give that consolidation which will be equivalent to 100% when overload is removed - in this case, approximately 6 ft is required.

The cross-section of the embankment must be so chosen that it is stable at all stages of construction. The most critical time will be when the embankment has just reached its greatest height. A lower factor of safety (say 1.2) may be used than is generally considered necessary (1.5) as stability will increase during the overload period. Stability analyses are based on the shear strengths predicted by tests. The results of these analyses indicate that side slopes of 2 to 1 should be satisfactory. Further stability analyses should be made for intermediate stages of loading. Shearing strength of the embankment material has been assumed as 1000 lb/sq.ft. a figure which tests on embankment material at Sulphur Beach have shown to be easily obtained.

The design calculations, given in the Appendices, are of a preliminary nature only, and include many rough approximations. More refined methods, based on further soil tests, would be required before any work was undertaken.

The total time required might be reduced by -

(a) installing larger sand drains at smaller spacing,

(b) increasing the loading rate, to achieve a lower degree of consolidation at the end of the construction period. This would make flatter side-slopes necessary to ensure stability.

(c) increasing the overload, so that the desired consolidation would be achieved in a shorter time.

Materials and Equipment

As with any embankment, a suitable source of filling is required, together with earthmoving and compacting equipment.

The driving of sand drains may involve the use of equipment not readily available, but the writer considers that equipment used for driving cast-in-place concrete piles could be easily adapted for the purpose.

Sand for the blanket and drains might be an expensive item in Auckland, but suitably graded scoria would probably be satisfactory.

For field control observations the piezometers could be made up locally and operated without difficulty.

CONCLUSIONS

1. It is undoubtedly possible to build a stable embankment of reasonable proportions, across the site chosen using vertical sand drains.

2. It is estimated that the total time required to complete the project would be about one year. This time might be reduced somewhat by modifications of the design at some increase in cost.

3. Suitable materials and equipment, perhaps requiring slight modification, are available locally.

4. A preliminary design only, is given in the report. More refined methods of estimating soil strength, settlement and stability, based on further soil mechanics tests, would be required before any work was undertaken.

5. The choice between short span bridging and an embankment with vertical sand drains can only be made after taking out comparative estimates. This is beyond the scope of the report.

6. Even for low embankments as would be required for approaches to short span bridging, the advantages of vertical sand drains should not be overlooked. By eliminating settlement their initial cost may be more than offset by reduction of charges for relevelling and maintenance in the future.

COMMENT

By F. M. Hanson

Mr Parsons of the Ministry of Works and Mr Taylor of the School of Engineering, Auckland University, have presented comprehensive papers on a class of work which will be somewhat new to a number of New Zealand engineers. It will be realised that these voluminous papers on vertical sand-drains have called for an outstanding effort by two otherwise fully employed engineers.

Because of the time needed for preparation, these papers have only just come to hand. Since a very busy period is about to commence for the Government Printer it is not possible for him to handle the full papers in the time available. It is not desired to hold up publication of the other papers and therefore only abridged reports by Messrs Parsons and Taylor will be presented now. This may not be a disadvantage for a further period of observation on any additional settlement may provide data which will enhance the value of the papers. It might well be preferable for full publication to be left to a later date, or better still, the Authors may choose to submit their work to the New Zealand Institution of Engineers for the wider discussion by Institution Members.

May I suggest that some estimates should be prepared of the respective costs of the two alternatives, i.e. bridging or vertical sand-draining and filling. This will be useful information, but at the same time, no matter which alternative may show up in the most favourable light from the cost aspect it will not alter the value of these papers on vertical sand-drains.

At the right time I certainly would like to offer comment and, of course, there will be others whose views should be recorded on work of this nature.

R. E. Owen, Government Printer, Wellington, New Zealand, 1959

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